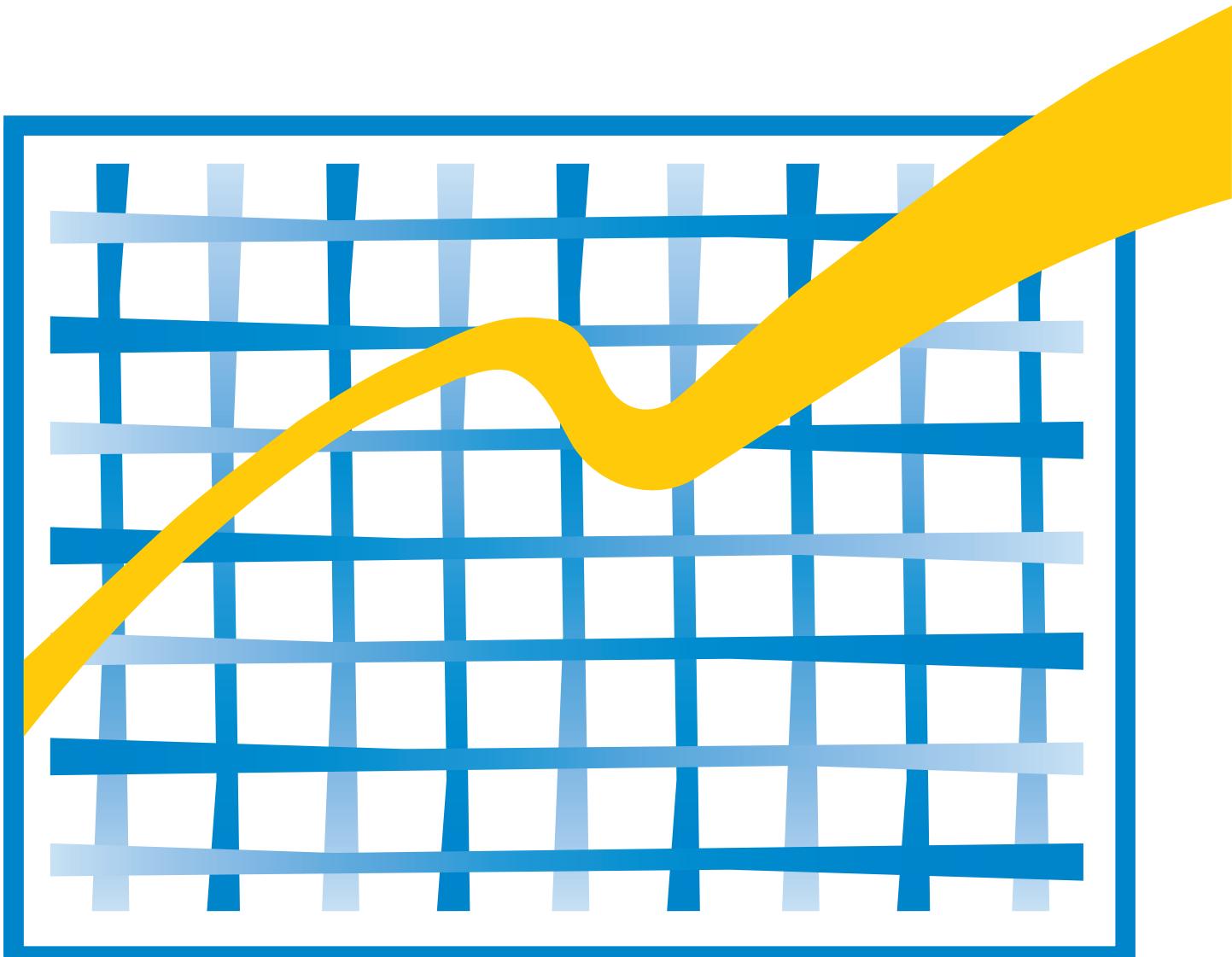


A GUIDE TO PROGRAMMING IN

JAVA™

Java™ 2 Platform Standard Edition 5



Beth Brown

 **Lawrenceville
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A Guide to Programming in Java™

Java™ 2 Platform Standard Edition 5

Beth Brown

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by



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We have strived to make this the clearest and most comprehensive Java text available. Our primary objective in this text is to present material in clear language with easy to follow examples. To meet this objective, we use our teaching experiences as well as the feedback, comments, and suggestions from other experienced instructors to determine how best to present programming concepts.

For the best classroom experience for both the student and the instructor, our comprehensive text book includes hands-on reviews, critical-thinking questions, and exercises of varying difficulty levels. Additionally, our Teacher Resource Materials correlate directly to the text book and offer teaching hints for explaining difficult concepts, additional lessons and exercises, and a comprehensive question bank for creating tests, quizzes, and reviews. The Teacher Resource Materials include the applications, Case Studies, and vocabulary from the text book, as well as answers to all the reviews and exercises.

It is our belief that learning to program offers the student an invaluable opportunity to develop problem-solving skills. The process of defining a problem, breaking it down into a series of smaller problems, and finally writing an application to solve it exercises a student's logical abilities. Additionally, the student is made aware of the capabilities and limitations of a computer and soon realizes that the programmer—the human element—is more important than the machine.

A Guide to Programming in Java is written for a one-term or two-term course. No previous programming experience is required or assumed. It is our goal that this text provide students the best possible introduction to programming using Java and to prepare them for further study in the IT/programming/computer science field.

Design and Features

Programming Concepts This text emphasizes the fundamental concepts of programming so that this knowledge can be applied to other programming languages.

Problem Solving From the very beginning, students are taught to implement programming solutions with proper algorithm design and code conventions.

Programming Style Throughout the text, proper programming style is emphasized so that students can make their applications easy to read, modify, and debug.

Demonstration Applications and Runs Many demonstration applications are included, complete with sample runs, so that students are shown both proper programming techniques and the output actually produced by an application.

Reviews Numerous reviews are presented throughout each chapter to provide immediate reinforcement of newly learned concepts. Solutions to the reviews are included on the Teacher Resource Materials CD.

Case Studies Most chapters end by stating a problem, developing an appropriate algorithm, and then implementing the solution. The process of specification, design, implementation, and debugging and testing is clearly outlined.

Chapter Summaries Each chapter ends by summarizing the concepts and statements covered in the chapter.

Vocabulary Sections Each chapter contains a vocabulary section that defines new terms. A separate section lists Java keywords, statements, and classes.

Critical Thinking Written response questions that require critical thinking from the student are included at the end of each chapter.

Exercises Each chapter includes a large set of exercises of varying difficulty, making them appropriate for students with a range of abilities. Most exercises include a demonstration run to help make clear what output is expected from the student's application. Exercises based on previous work are marked with a symbol. Answers to the exercises are included on the Teacher Resource Materials CD.

Indexes In addition to a standard index, an index of the applications presented in the text is also included.

Appendix A chart of Unicode symbols is included.

Online Resources Materials that complement and extend this text are free for download and distribution in your class. Information about various Java compilers is available. Supplemental chapters cover operating systems, personal finances, introduction to computers, and keyboarding skills are also provided. Students can download all the files needed to complete the reviews and exercises from www.lpdatafiles.com.

Teacher Resource Materials

Our Teacher Resource Materials correlate directly to the text book and provide all the additional materials required to offer students an excellent computer applications course. The Teacher Resource Materials feature:

- **START_HERE.htm** Help files and a guide for using the text and resource materials.
- **Lesson Plans** Lessons in PDF format keyed to the chapters in the text. Each lesson includes assignments, teaching notes, worksheets, and additional topics.
- **Tutorials** Flash movie files that provide animations to illustrate searching and sorting concepts. Each movie is keyed to the text.
- **PowerPoint Presentations** Topics keyed to the text are in PowerPoint files for presentation.
- **Vocabulary** Word files of the vocabulary presented in the text.
- **Rubrics** Rubrics keyed to exercises in the text for assessment.
- **Worksheets** Programming assignments that supplement the exercises in the text provide additional reinforcement of concepts.
- **Critical Thinking Answers** Answers for the critical thinking questions presented in the text.
- **Data files** All the files the student needs to complete the reviews and exercises in the text, as well as the files needed to complete the worksheets and tests.
- **ExamView® Software** Question banks keyed to the text and the popular **ExamView®** software are included to create tests, quizzes, and additional assessment materials.
- **Answer files** Answers to the reviews, exercises, worksheets, and tests.

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Thanks also to Joseph Dupree in our Customer Relations Department for some of the original drawings included in this text.

The success of this and all of our texts is due to the efforts of Heidi Crane, Vice President of Marketing at Lawrenceville Press. Joseph Dupree and Christina Albanesius run our Customer Relations Department and handle the thousands of orders we receive in a friendly and efficient manner. Michael Porter is responsible for the excellent service Lawrenceville Press offers in the shipping of orders.

About the Author

Beth A. Brown, a Computer Science graduate of Florida Atlantic University, is director of development at Lawrenceville Press where she has coauthored a number of programming and applications texts and their accompanying Teacher Resource Materials. She has taught computer applications and programming at the high school level.

Chapter Expectations

Chapter 1 – An Introduction to Computers

After completing Chapter 1, students will be able to:

1. Compare and contrast various input, output, and storage devices.
2. Identify hardware components and explain their function.
3. Demonstrate knowledge of operating systems.
4. Discuss different computer classifications and compatibility issues.
5. Differentiate among the levels of programming languages.
6. Describe communication and networking components.
7. Understand the binary number system.
8. Describe how data is stored in memory and in files.
9. Use Internet services to access information and share resources.
10. Demonstrate proper etiquette and knowledge of acceptable use policies when using a network.
11. Discuss social and ethical issues associated with computer use.

Chapter 2 – Applets and Web Programming

After completing Chapter 2, students will be able to:

1. Define terminology associated with the World Wide Web.
2. Discuss the impact of programming on the World Wide Web community.
3. Create HTML documents.
4. Explain how a web browser interprets an HTML document.
5. Use JavaScript to demonstrate how scripts can enhance a website.
6. Create simple Java applets.
7. Specify custom values for a Java applet that has been placed in an HTML document.
8. Apply a style sheet to an HTML document.

Chapter 3 – Introducing Java

After completing Chapter 3, students will be able to:

1. Define terminology associated with object-oriented programming.
2. Explain why Java is a widely used programming language.
3. Create Java applications.
4. Describe the process involved in executing a Java application.
5. Display and format program output.
6. Annotate code properly with comments, formatting, and indentation.
7. Explain the importance of using code conventions.
8. Demonstrate algorithm design as a problem-solving strategy.
9. Use visual organizers to design solutions.

Chapter 4 – Variables and Constants

After completing Chapter 4, students will be able to:

1. Declare and initialize variables and constants using the appropriate data type.
2. Choose legal identifiers that follow good programming style.
3. Differentiate between primitive and abstract data types.
4. Explain how to access Java packages.
5. Demonstrate how to read data from an input stream.
6. Write numeric expressions.
7. Apply type casting.
8. Format numeric output.
9. Identify Java keywords.
10. Differentiate between syntax and logic errors.
11. Understand run-time exceptions.
12. Read and understand a problem description, purpose, and goals.

Chapter 5 – Conditional Control Structures

After completing Chapter 5, students will be able to:

1. Demonstrate the use of decision structures to control the flow of a program.
2. Describe how a roundoff error can occur.
3. Generate random numbers.
4. Write compound Boolean expressions.
5. Access methods in the Math class.
6. Modify existing code.
7. Develop code with correct and efficient use of conditional control structures.
8. Select appropriate test data.
9. Create and modify solutions to problems.

Chapter 6 – Loop Structures and Strings

After completing Chapter 6, students will be able to:

1. Demonstrate the use of repetition control structures.
2. Explain how infinite loops can occur.
3. Differentiate between counters and accumulators.
4. Use various tools and techniques to debug an application.
5. Manipulate and compare strings using the String class and its methods.
6. Develop code with correct and efficient use of repetitive control structures.
7. Apply problem solving strategies.

Chapter 7 – Chapter Methods

After completing Chapter 7, students will be able to:

1. Use top-down development and procedural abstraction to develop problem solutions.
2. Write methods.
3. Use method parameters.
4. Demonstrate the use of method overloading.
5. Return values from a method.
6. Write appropriate method documentation, including pre- and post-conditions.
7. Identify boundary cases and generate appropriate test data.
8. Describe code conventions that apply to methods.

Chapter 8 – Classes and Object-Oriented Development

After completing Chapter 8, students will be able to:

1. Understand and instantiate objects.
2. Design and implement a class.
3. Apply functional decomposition.
4. Apply appropriate naming conventions to a class.
5. Explain the difference between accessor, modifier, and helper methods.
6. Write constructors.
7. Compare and contrast instance and class members.
8. Understand class specifications and the relationships among the classes.
9. Understand and implement a given class hierarchy.
10. Apply encapsulation.
11. Identify reusable code from existing code.

Chapter 9 – Inheritance and Polymorphism

After completing Chapter 9, students will be able to:

1. Extend a class using inheritance.
2. Explain an is-a relationship.
3. Implement a subclass.
4. Define and demonstrate polymorphism.
5. Understand abstract classes.
6. Declare and implement an interface.
7. Extend existing code using inheritance.

Chapter 10 – Arrays

After completing Chapter 10, students will be able to:

1. Describe types of problems that benefit from the use of arrays.
2. Create one and two dimensional arrays.
3. Include array parameters in a method declaration.
4. Understand how to implement arrays with meaningful indexes.
5. Apply offset array indexes.
6. Manipulate characters in a string.
7. Understand the digital code, Unicode.
8. Apply search algorithms to an array.
9. Use methods in the ArrayList class.
10. Demonstrate the use of the Wrapper classes.

Chapter 11 – GUIs and Event-Driven Programming

After completing Chapter 11, students will be able to:

1. Design graphical user interfaces.
2. Use component classes in the Java swing package.
3. Create event-driven applications.
4. Control the layout of an interface using layout managers.
5. Use text fields and combo boxes to obtain user input.
6. Apply color and add images to an interface.

Chapter 12 – Files and Exception Handling

After completing Chapter 12, students will be able to:

1. Use the File class to create objects that represent a file.
2. Write exception handlers.
3. Understand file streams.
4. Read the contents of an existing file.
5. Process numeric data.
6. Create an output file stream.
7. Explain the object serialization and deserialization processes.

Chapter 13 – Recursion and Advanced Algorithms

After completing Chapter 13, students will be able to:

1. Implement the selection sort algorithms.
2. Sort objects using the Comparable interface.
3. Implement the insertion sort algorithm.
4. Define and demonstrate recursion.
5. Implement the mergesort algorithm.
6. Implement the binary search algorithm.
7. Explain the recursive technique, depth-first searching.
8. Analyze algorithms for efficiency.
9. Design and document sequential search algorithms.

Chapter 14 – Data Structures

After completing Chapter 14, students will be able to:

1. Explain how data structures, such as stacks and queues, can be used to organize data.
2. Use and implement well known data structures.
3. Describe standard operations associated with data structures.
4. Choose appropriate data structures.
5. Differentiate between a LIFO and FIFO structure.

Table of Contents

Chapter 1 – An Introduction to Computers

Desktop Computing	1
Operating Systems and Environment.....	2
Mobile Computing.....	4
Programming Languages.....	5
Networks.....	6
Number Systems	9
Storing Data in Memory	10
What is a File?	11
Storage Devices.....	12
Intranet, Extranet, Internet	13
Telecommunications	14
Internet Services: Web, E-mail, and Mailing Lists	15
Finding Information on the Web and Downloading Files.....	16
Internet Privacy Issues	18
Internet Acceptable Use Policy	19
The Social and Ethical Implications of Computer Use	19
Protecting Computer Software and Data	20
The Ethical Responsibilities of an IT Professional.....	22
Chapter Summary	22
Vocabulary	25
Review Questions	29
Exercises	32

Chapter 2 – Applets and Web Programming

The World Wide Web.....	35
HTML	36
Creating an HTML Document	37
Review: hello_world.htm	38
Review: Computer Viruses Website – part 1 of 6.....	38
JavaScript.....	38
Review: welcome.htm.....	39
Review: Computer Viruses Website – part 2 of 6.....	39
Using Scripts to Enhance a Website	40
Review: Computer Viruses Website – part 3 of 6.....	41
Review: System Check – part 1 of 2.....	41
Java Applets	41
Creating Java Applets	41
Drawing Shapes and Adding Color	43
Review: Hot Air Balloon	44
Placing an Applet in an HTML Document	44
Applet Parameters	44
Review: System Check – part 2 of 2.....	45
HTML Tags	45
Review: Computer Viruses Website – part 4 of 6.....	47
Hyperlinks, Tables, and Images.....	47
Review: Computer Viruses Website – part 5 of 6.....	49
Style Sheets	49
Review: Computer Viruses Website – part 6 of 6.....	51
Chapter Summary	51
Vocabulary	53
HTML Tags	54
Critical Thinking.....	55
Exercises	56

Chapter 3 – Introducing Java

Why Program in Java?.....	59
Objects, Classes, and Packages	59
A Java Application	61
Executing a Java Application.....	62
Review: Greeting.....	62
Displaying Output	63
Review: AboutMe – part 1 of 2.....	64
Formatting Output.....	64
Review: AboutMe – part 2 of 2.....	65
Code Conventions	65
Algorithm Design	66
Chapter Summary	67
Vocabulary	69
Java	70
Critical Thinking.....	71
Exercises	72

Chapter 4 – Variables and Constants

Declaring Variables.....	77
Using Variables.....	78
Review: RectanglePerimeter.....	79
Primitive Data Types	79
Review: Distance – part 1 of 2.....	79
Abstract Data Types.....	80
Java Packages	80
Obtaining a Value from the User.....	81
Review: Distance – part 2 of 2	82
Numeric Expressions.....	83
Review: Digits.....	84
Type Casting	84
Review: GradeAvg – part 1 of 2	85
Review: TempConverter.....	85
Formatting Numeric Output.....	86
Assignment Operators	86
Review: GradeAvg – part 2 of 2	87
Using Named Constants	87
Identifiers and Keywords	88
Review: CircleCircumference – part 1 of 2....	88
Programming Errors	88
Chapter 4 Case Study	90
Chapter Summary	93
Vocabulary	95
Java	96
Critical Thinking.....	97
Exercises	99

Chapter 5 – Conditional Control Structures

The if Statement.....	105
Roundoff Error	106
Review: SurfsUp – part 1 of 3	106
The if-else Statement.....	106
Review: SurfsUp – part 2 of 3	107
Review: CircleCircumference – part 2 of 2... ..	107
Nested Statements.....	107
Review: Stages	107
The if-else if Statement	108
Review: SurfsUp – part 3 of 3	108
Review: Discriminant.....	108
The switch Statement.....	109
Review: Hurricane	110
Generating Random Numbers.....	110
Review: RandomNum.....	111
Compound Boolean Expressions.....	112
Review: Delivery	113
The Math Class.....	113
Review: PerfectSquare.....	114
Chapter 5 Case Study	114
Review: RPS – part 1 of 2	118
Review: RPS – part 2 of 2	118
Chapter Summary	119
Vocabulary	120
Java	121
Critical Thinking.....	122
Exercises	123

Chapter 6 – Loop Structures and Strings

The while Statement	131
The do-while Statement	131
Infinite Loops	132
Review: Prompter	133
Counters and Accumulators.....	133
Review: Evens.....	134
Review: NumbersSum	134
Review: PercentPassing.....	134
The for Statement	135
Review: Factorial	136
Review: OddSum	136
Debugging Techniques	136
Review: Variable Trace	137
The String Class	138
Review: AccountSetup	139
Comparing Strings.....	140
Review: FormalGreeting.....	141

Chapter 6 Case Study	141
Review: WordGuess.....	146
Chapter Summary	146
Vocabulary	148
Java	148
Critical Thinking.....	149
Exercises	150

Chapter 8 Case Study	196
Review: RPS2 – part 1 of 2	202
Review: RPS2 – part 2 of 2	202
Chapter Summary	202
Vocabulary	204
Java	205
Critical Thinking.....	206
Exercises	208

Chapter 7 – Methods

Program Development Using Methods	157
Writing Methods	159
Review: TimeConverter.....	160
Method Parameters.....	160
Review: SpanishNumbers	161
Review: DisplayBox – part 1 of 2	162
Method Overloading	162
Review: DisplayBox – part 2 of 2	163
The return Statement.....	163
Review: Exponentiation	164
Documenting Methods	164
Review	165
Chapter 7 Case Study	165
Review: GradeConverter.....	171
Chapter Summary	171
Vocabulary	173
Java	173
Critical Thinking.....	174
Exercises	175

Chapter 9 – Inheritance and Polymorphism

Extending a Class.....	213
Implementing a Subclass	214
Review: Puck – part 1 of 2.....	216
Polymorphism	217
Review: Music – part 1 of 2.....	221
Abstract Classes	222
Review: Music – part 2 of 2.....	225
Interfaces	225
Review: Disk	227
Review: Puck – part 2 of 2.....	227
Review: Rectangle – part 4 of 4	227
Review: Rectangle – part 4 of 5	227
Chapter 9 Case Study	227
Review: SalesCenter.....	234
Chapter Summary	234
Vocabulary	236
Java	236
Critical Thinking.....	237
Exercises	238

Chapter 8 – Classes and Object-Oriented Development

What is an Object?	179
Designing and Writing a Class	180
Review: Circle – part 1 of 4	182
Review: Coin – part 1 of 2	182
Writing Constructors.....	183
Review: Circle – part 2 of 4	184
Review: Rectangle – part 1 of 5	184
Instance and Class Members.....	184
Review: Circle – part 3 of 4	185
Review: Rectangle – part 2 of 5	185
The Object Class	185
Review: Circle – part 4 of 4	187
Review: Rectangle – part 3 of 5	187
Review: Coin – part 2 of 2	187
Classes Using Classes.....	187
Review: Bank	191
Object-Oriented Development	191
Review: Carnival.....	195

Chapter 10 – Arrays

Declaring Arrays.....	239
Using Arrays.....	240
Review: StudentRoster	241
Review: Squares	241
Review: Reverse	241
Array Parameters	241
Arrays with Meaningful Indexes	242
Review: DiceRolls – part 1 of 2.....	243
Review: DiceRolls – part 2 of 2.....	243
Review: NumberCounts.....	243
Characters and Arrays	244
Review: CountLetters	246
Review: NameBackwards	246
Searching an Array.....	246
Review: FindName	247
Two-Dimensional Arrays.....	247
The ArrayList Class	252

Wrapper Classes.....	253
Review: HighestGrade	255
Chapter 10 Case Study	255
Review: LocalBank	264
Chapter Summary	264
Vocabulary	265
Java	265
Critical Thinking.....	266
Exercises	267

Chapter 11 – GUIs and Event-Driven Programming

What is a GUI?.....	275
The Swing Package	275
Review: Name – part 1 of 2.....	278
The JButton Class	278
Handling Events.....	279
Review: Name – part 2 of 2.....	281
Review: NumClicks	281
Controlling Layout.....	281
Review: Sunflower	284
Review: Riddle.....	284
Getting Input from the User.....	285
Review: DivisibleBy3	287
Combo Boxes	288
Review: MetricConversion.....	290
Changing Colors	291
Adding Images.....	292
Review: Roll	294
Using Nested Classes to Handle Events.....	295
Chapter 11 Case Study	298
Review: BreakAPlate	303
Chapter Summary	304
Vocabulary	305
Java	306
Critical Thinking.....	307
Exercises	309

Chapter 12 – Files and Exception Handling

What is a File?.....	311
The File Classes	311
Review: MyFile – part 1 of 2	312
Handling Exceptions	312
Review: MyFile – part 2 of 2	313
The File Streams	313
The FileReader and BufferedReader Classes	314
Review: Assignment.....	315

Processing Numeric Data	316
Review: Stats – part 1 of 2	317
The FileWriter and BufferedWriter Classes	317
Review: Stats – part 2 of 2	319
Object Serialization.....	319
Review: Roster	322
Chapter 12 Case Study	323
Review: LocalBank2	328
Chapter Summary	329
Vocabulary	330
Java	330
Critical Thinking.....	331
Exercises	332

Chapter 13 – Recursion and Advanced Algorithms

Selection Sort	337
Sorting Objects	339
Review: ArrayListSort	341
Insertion Sort	341
Review: ObjectsInsertionSort	343
Recursion.....	343
Review: RecursiveFactorial.....	345
Mergesort	345
Review: ObjectsMergesort	348
Binary Search.....	349
Review: SearchLocations	351
Review: ObjectsBinarySearch	352
Review: BinarySearch2	352
Depth-First Searching	352
Review: DetectColonies – part 1 of 3.....	356
Review: DetectColonies – part 2 of 3.....	356
Review: DetectColonies – part 3 of 3.....	356
Algorithm Analysis	356
Chapter Summary	357
Vocabulary	358
Java	358
Critical Thinking.....	359
Exercises	361

Chapter 14 – Data Structures

The Stack Data Structure	365
The Stack Class.....	366
Review: Stack2.....	368
Review: Stack3.....	369
The Queue Data Structure.....	369
The Queue Class	370
Review: Queue2.....	372
Review: Queue3.....	372

The Linked List Data Structure	373
The LinkedList Class.....	374
Review: LinkedList – part 1 of 3	376
Review: LinkedList – part 2 of 3	376
Review: LinkedList – part 3 of 3	376
Chapter Summary	377
Vocabulary	377
Critical Thinking.....	378
Exercises	379

Appendix A – Unicode

Unicode.....	381
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Index

Index	383
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Chapter 1

An Introduction to Computers

This chapter discusses current computing technologies, networks, the Internet, and the World Wide Web. Issues related to computers, including privacy, viruses, and copyright are also discussed.

Desktop Computing

A desktop computer and its components are designed to fit on or under a desk:



Scanner

A scanner is an input device that uses a laser to create a digital image from artwork such as photos and drawings. The digitized image can then be incorporated into an electronic document.

Printers

A laser printer uses a laser and toner to generate characters and graphics on paper. An ink jet printer uses an ink cartridge to place very small dots of ink onto paper to create characters and graphics.

- The physical components of the computer, such as the monitor and system unit, are called *hardware*.
- Data and instructions are entered into the computer using *input devices*, such as a keyboard, mouse, scanner, microphone, digital camera, CD-RW/DVD drive, and disk drive.
- A PC becomes much more versatile when *peripheral devices*, such as printers and scanners, are added. A peripheral device is attached to a *port* on the computer. There are different types of ports, such as serial, parallel, FireWire, USB, and Bluetooth ports.
- Computers process data into meaningful, useful information. Processed data is conveyed using *output devices*. Monitors and printers display data, CD-RWs, disk drives, and memory keys store data, and speakers communicate audio output.

The base unit also contains the *motherboard*, which is the main circuit board. The motherboard contains several components:

- *Expansion boards* are circuit boards that connect to the motherboard to add functionality to the computer. Examples include sound cards and video adapters.

Real-time Clock

A battery chip called a real-time clock keeps track of the date and time in a computer even when the computer is off.

CPU Manufacturers

Intel and AMD are two processor manufacturers. Processors are identified by a model name or number, such as Pentium® 4, Itanium® 2, and Opteron™. The Intel Pentium 4 (P4) CPU has a clock rate of 3.06 GHz. The AMD Opteron CPU has a clock rate of 2.4 GHz. These CPUs contain more than 40 million transistors on a single chip.

Integrated Circuits

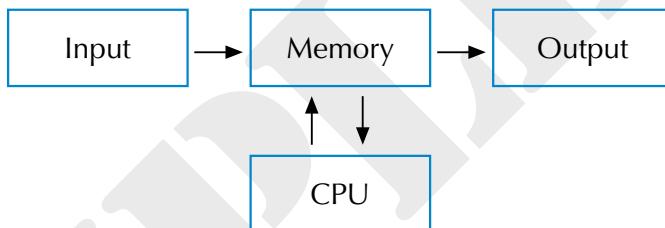
Integrated circuits, also called chips, are created from silicon wafers which are etched with intricate circuits and coated with a metallic oxide to allow the circuits to conduct electricity. The silicon wafers are housed in special plastic cases that have metal pins. The pins allow the integrated circuits to be plugged into circuit boards.

BIOS

BIOS (basic input/output system) is firmware that contains the computer's start-up instructions. Firmware is instructions or data that is written onto ROM.

- The **CPU** (Central Processing Unit) or processor processes data and controls the flow of data between the computer's other units. Within the CPU is the ALU (Arithmetic Logic Unit), which can perform arithmetic and logic operations. It can also make comparisons, which is the basis of the computer's decision-making power. The ALU is so fast that the time needed to carry out a single addition is measured in nanoseconds (billions of a second). The speed at which a CPU can execute instructions is determined by the computer's clock rate. The clock rate is measured in *megahertz* (MHz, million of cycles per second) or *gigahertz* (GHz, billion of cycles per second).

- A **bus** is a set of circuits that connect the CPU to other components. The data bus transfers data between the CPU, memory, and other hardware devices on the motherboard. The *address bus* carries memory addresses that indicate where the data is located and where the data should go. A *control bus* carries control signals. All data flows through the CPU:



- Memory in the form of *integrated circuits* (ICs) stores data electronically. *ROM* (Read Only Memory) contains the most basic operating instructions for the computer. The data in ROM is a permanent part of the computer and cannot be changed. *RAM* (Random Access Memory), also called *primary or main memory*, is memory where data and instructions are stored temporarily. Data stored in RAM can be written to *secondary memory*, which includes any type of storage media, such as a floppy disk, hard disk, memory key, or CD-RW. Secondary memory must be copied into primary memory before it is processed by the CPU. *SRAM* (Static Random Access Memory) is high-speed memory referred to as *cache* (pronounced "cash"). This memory is used to store frequently used data so that it can be quickly retrieved by an application.

Operating Systems and Environment

A desktop computer also contains programs, or software. *Operating system (OS) software* is run automatically when the computer is turned on and is used to control processing and peripherals, run application software, and control input and output, among other tasks. Desktop operating system software includes Windows, Mac OS X Tiger, Unix, and Linux. Each of these operating systems have different features and functions. *Applications software* is written by programmers to perform a specific task, such as a word processor.

The type of OS a computer can run depends on the computer hardware, and can be multiuser, multiprocessing, multitasking, multithreading, or

Mainframes and Supercomputers

A mainframe is a large computer system that supports multi-user applications and tasks that require the storage and processing of huge amounts of information. Large corporations, airlines, banks, government agencies, and universities use mainframes.

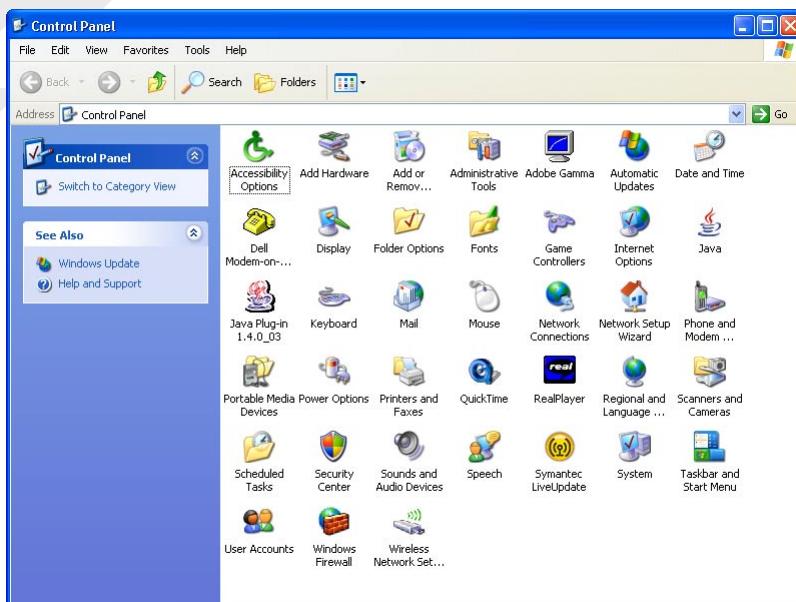
A supercomputer is the fastest and most powerful type of computer. Supercomputers focus on executing a few programs as fast as possible and are used for weather forecasting and nuclear energy research.

TIP For information on a specific operating system, refer to the appropriate chapter at Lvp.com.

real time. A *multiuser OS* is supported by mainframes and minicomputers and allows for two or more users at the same time. The terms *multiprocessing* and *multitasking* are often used interchangeably when referring to an OS that allows for multiple applications ("processes" or "tasks") to run at the same time. This type of OS determines how to divide processor time between running applications. A multiprocessing OS should not be confused with a multiprocessor computer system, which has more than one processor and performs *parallel processing* because the processors are used simultaneously for multiprocessing. *Multithreading* refers to an OS that can execute different parts of a single program, called threads, at the same time. A *real-time OS* responds to input immediately. This type of OS is used in situations where immediate feedback is required, such as navigation systems or medical monitoring equipment.

Environment refers to a computer's hardware and software configuration. For example, a Windows XP environment means that the computer is running the Windows XP Professional OS software and hardware includes a 300MHz processor or better, 128MB of RAM or more, and at least 1.5GB of hard disk space. The hardware requirements are based on what will be needed to allow the OS software to properly manage the computer's tasks. The term *platform* is sometimes synonymous with environment.

Environment types vary widely and can refer to the computer type or the way the user interacts with the computer as well as the software/hardware configuration. A *desktop environment* refers to a desktop or notebook computer running an OS designed for the typical hardware found in a desktop or notebook computer. A *multiuser environment* is sometimes called time sharing because each user gets a portion of the processor's "time." A *distributed environment* shares the load of processing among several computers. When discussing environments, a distinction is usually made between multiprocessing and multitasking. A *multiprocessing environment* means that more than one processor is being used for executing an application, and a *multitasking environment* is one in which processing time for multiple applications is divided among one processor. Most environments run an OS with a graphical user interface (GUI):



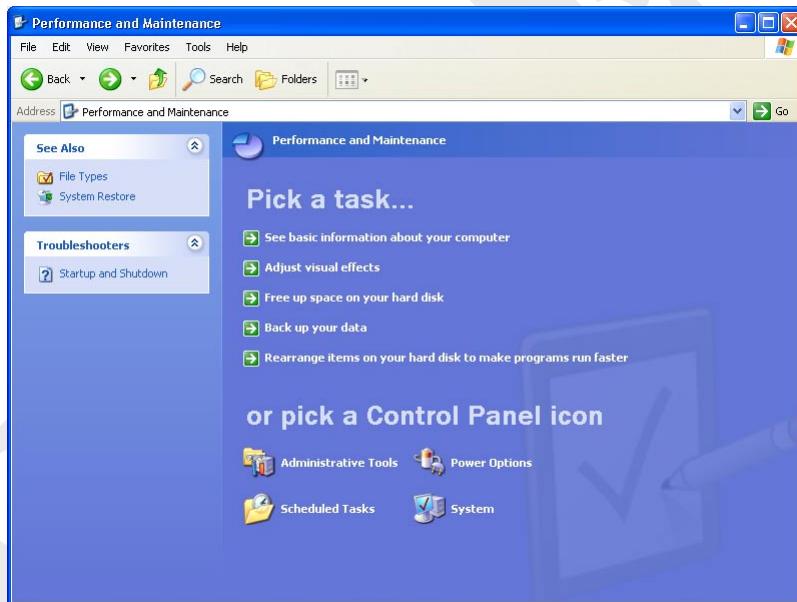
Windows XP Operating System

utility program

memory-resident

The functions of an OS are based on the intended OS platform. Functionality is implemented through utility programs that are written as part of the OS. A *utility program* has one clearly defined task, unlike an application which can usually perform many different tasks. Utility programs are run by the OS to manage input and output, read and write to memory, manage the processor, maintain system security, and manage files and disks. One type of utility program, called a *device driver*, is needed for printing, viewing graphics, using a CD/DVD drive, and using peripherals in general. Some utility programs load when the computer starts and are called *memory-resident* because they are always in memory.

Features are added to an OS by incorporating utility programs to perform tasks that are in addition to the tasks required to run the computer. For example, an OS intended for a desktop or notebook environment will often include utilities for disk defragmentation, text narration and other accessibility tools, and system restore and backup tools. For example:



Windows XP Utilities

Mobile Computing

Bluetooth

Bluetooth is a wireless technology used to allow mobile computing devices to communicate.

Improved technology has allowed the miniaturization of computer components and special long-lasting batteries. Computers now come in many shapes, sizes, and with many levels of features. Among these computers are notebooks, tablets, handhelds, smart phones, and wearables. Because of their portability, these types of computers are classified as mobile computing devices:

- A *notebook computer* is a portable, lightweight computer with a CPU, memory, and hard disk space comparable to that of a typical desktop computer.
- A *tablet PC* is a computer designed similar to a pad of paper and a pencil. Users simply "write" on a screen with a device called a *stylus* that is shaped like a thin pencil. Handwriting recognition software is used to interpret a user's handwriting. A keyboard can also be attached.

Handheld Computers

Handheld computers are widely used in occupations that require constant travel, such as parcel delivery, meter reading, and sales.

- *Handheld computers*, also called PDAs, are palm-sized and contain applications for storing contact information, schedules, lists, and games. Handhelds come with a stylus for input and have a screen that is several inches vertically. Many types of application software have been written for handhelds, including spreadsheets and word processors. Some handhelds recognize handwriting, have a built-in keyboard, include a cellular phone, and provide Internet access.
- *Smartphones* are cellular phones that are able to send and receive e-mail messages and access the Internet. Some smartphones have digital camera, MP3 player, and color display capabilities.
- *Wearable computers* vary greatly in size and application. MP3 players have been incorporated into clothing, and one type of wearable computer includes voice recognition. Wearable computers are also in the form of goggles, which incorporate a monitor, digital camera, ear bud, and microphone. Wrist-top computers are worn like a traditional wrist watch and work as a pager, provide Internet access, and contain other features usually found in a handheld PC.

cross-platform connectivity

One issue involved with using so many types of PCs is *cross-platform connectivity*, which is the ability for one type of PC to link to and share data with a different type of PC. Notebook and desktop PCs typically have good cross-platform connectivity because their file formats can be used on either computer. Tablets and handhelds use a different OS and generate different file formats, requiring special hardware and software to use their files on a desktop or notebook PC. Wearable computers typically have a cable that allow a connection to other types of PCs, but special software must be used to communicate between the devices.

Programming Languages

A *programming language* is a set of words, codes, and symbols that allow a programmer to give instructions to the computer. Many programming languages exist, each with their own rules, or syntax, for writing these instructions.

Programming languages can be classified as low-level and high-level languages. *Low-level programming languages* include machine language and assembly language. Machine language, which is referred to as a first generation programming language, can be used to communicate directly with the computer. However, it is difficult to program in machine language because the language consists of 0s and 1s to represent the status of a switch (0 for off and 1 for on). Assembly language uses the same instructions and structure as machine language but the programmer is able to use meaningful names or abbreviations instead of numbers. Assembly language is referred to as a second generation programming language.

High-level programming languages, which are often referred to as third generation programming languages (3GL), were first developed in the late 1950s. High-level programming languages have English-like instructions and are easier to use than machine language. High-level programming languages include Fortran, C, Basic, COBOL, and Pascal. In order for the computer to understand a program written in a high-level language, programmers convert the source code into machine language using a compiler or an interpreter. A *compiler* is a program that converts an entire program

Fourth and Fifth Generation Languages

Fourth generation languages (4GL), such as SQL, have higher English-like instructions than most high-level languages and are typically used to access databases. Fifth generation languages are used for artificial intelligence.

interpreter

into machine code before the program is executed. An *interpreter* translates and executes an instruction before moving on to the next instruction in the program.

object-oriented programming

In the 1980s, *object-oriented programming* (OOP) evolved out of the need to better develop complex programs in a systematic, organized approach. The OOP approach allows programmers to create modules that can be used over and over again in a variety of programs. These modules contain code called classes, which group related data and actions. Properly designed classes encapsulate data to hide the implementation details, are versatile enough to be extended through inheritance, and give the programmer options through polymorphism. Object-oriented languages include Java, C++ and Visual Basic .NET.

Networks

A *network* is a combination of hardware and software that allows computers to exchange data and share software and devices, such as printers. Networks are widely used by businesses, universities, and other organizations because a network:

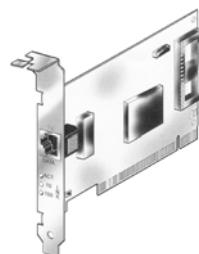
- allows users to reliably share and exchange data
- can reduce costs by sharing devices such as printers
- offers security options including password protection to restrict access to certain files
- simplifies file management through centralized software updates and file backups
- provides e-mail for network users

MAN and HAN

A MAN (Metropolitan Area Network) and a HAN (Home Area Network) are network technologies classified by the size of a network. A MAN is a high-speed network that typically connects LANs within a city or town. A HAN is used to connect personal devices within the home.

Networks are classified by their size, architecture, and topology. A common size classifications is *LAN* (Local-Area Network), which is a network used to connect devices within a small area such as a building or a campus. A *WAN* (Wide-Area Network) is used to connect devices over large geographical distances. A WAN can be one widespread network or it can be a number of LANs linked together.

The computers and other devices in a LAN each contain an expansion card called a *network interface card*:



Network interface card

Transmission Media

Computers must be connected in order to transmit data between the nodes. Cable transmission media includes twisted-pair wiring, coaxial cable, and fiber optic cable.

Wireless transmission media includes infrared signals, broadcast radio, cellular radio, microwaves, and communications satellites.

The amount of data and the speed at which data can travel over a media is called bandwidth, which is measured in bits per second (bps). Each transmission media has a specific length or range restriction, data transmission rate, and cost.

Ethernet

The Ethernet LAN protocol was developed by Bob Metcalfe in 1976. Ethernet uses a bus or star topology with twisted-pair wiring, coaxial cable, or fiber optic cable transmission media. Newer protocols include Fast Ethernet, which operates at 100 Mbps, Gigabit Ethernet which operates at 1 Gbps, and 10G Ethernet, which operates at 10 Gbps.

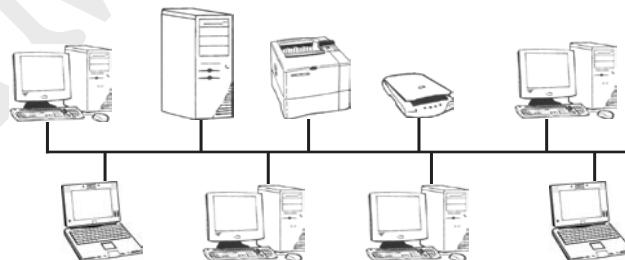
A cable plugs into the adapter card to connect one device to another to form a LAN. Cables are not required for network cards that have wireless capabilities. Network interface cards are available for desktop and mobile computers and take various other forms including an adapter card, a PC card, or a Flash memory card

Along with the physical, or hardware, aspects of setting up a network, there is also the software aspect. A *network operating system* is software that allow users and devices to communicate over the network. A *networked environment* refers to a set of networked computers running an OS that can handle the communication between the computers. The operating system installed must be capable of supporting networking functions, such as security access features and support for multiple users. Operating systems capable of network functions are available for Linux, Windows, Unix, and Mac. The network architecture, discussed next, must also be considered when choosing a network OS.

Network architecture includes the type of computers on the network and determines how network resources are handled. Two common models are peer-to-peer and client/server. In a *peer-to-peer* network, each computer on the network is considered equal in terms of responsibilities and resource sharing. A *client/server* network consists of a group of computers, called *clients*, connected to a server. A *server* is a computer with more RAM, a larger hard disk, and sometimes multiple CPUs that is used to manage network functions.

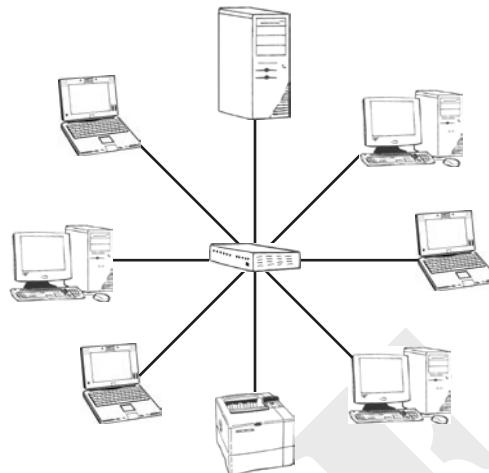
Physical topology refers to the arrangement of the nodes on a network. A *node* is a location on the network with a device capable of processing information, such as a computer or a printer. There are three common physical topologies:

- The *bus topology* is a physical LAN topology that uses a single central cable, called the *bus* or backbone to attach each node directly:



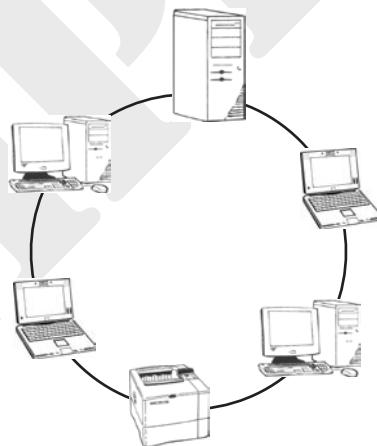
LAN using a bus topology

- In a *star topology*, each node is attached to a *hub*, which is a device that joins communication lines at a central location on the network:



LAN using a star topology

- In a *ring topology*, each node is connected to form a closed loop. A LAN with a ring topology can usually cover a greater distance than a bus or star topology:



LAN using a ring topology

- Wireless networks* use high frequency radio waves or infrared signals instead of cables to transmit data. A router/wireless access point device is used to allow nodes to transfer data wirelessly.

logical topology

Another type of topology is *logical topology*, which refers to the way data is passed between the nodes on a network. A LAN's logical topology is not always the same as its physical topology.

Network users are given a user name and password to log on to a network through a computer connected to the network. Users are also assigned a level of access to maintain security. Network users should follow a certain etiquette referred to as *netiquette*:

- Do not attempt to access the account of another user without authorization.
- Do not share your password, and change it periodically.
- Use appropriate subject matter and language, and be considerate of other people's beliefs and opinions.

Number Systems

binary number system

The electrical circuits on an IC have one of two states, off or on. Therefore, the *binary number system* (base 2), which uses only two digits (0 and 1), was adopted for use in computers. To represent numbers and letters, a code was developed with eight binary digits grouped together to represent a single number or letter. Each 0 or 1 in the binary code is called a *bit* (BInary digit) and an 8-bit unit is called a *byte*.

base 10

Our most familiar number system is the decimal, or *base 10*, system. It uses ten digits: 0 through 9. Each place represents a power of ten, with the first place to the left of the decimal point representing 10^0 , the next place representing 10^1 , the next 10^2 , and so on (remember that any number raised to the zero power is 1). In the decimal number 485, the 4 represents 4×10^2 , the 8 represents 8×10^1 , and the 5 represents 5×10^0 . The number 485 represents the sum $4 \times 100 + 8 \times 10 + 5 \times 1$ ($400 + 80 + 5$):

Decimal	Base 10 Equivalent
485	$4 \times 10^2 + 8 \times 10^1 + 5 \times 10^0 = 400 + 80 + 5$

Decimal	Binary	Base 2 Equivalent		
0	0	$= 0 \times 2^1 + 0 \times 2^0$	$= 0 \times 2 + 0 \times 1$	$= 0 + 0$
1	1	$= 0 \times 2^1 + 1 \times 2^0$	$= 0 \times 2 + 1 \times 1$	$= 0 + 1$
2	10	$= 1 \times 2^1 + 0 \times 2^0$	$= 1 \times 2 + 0 \times 1$	$= 2 + 0$
3	11	$= 1 \times 2^1 + 1 \times 2^0$	$= 1 \times 2 + 1 \times 1$	$= 2 + 1$
4	100	$= 1 \times 2^2 + 0 \times 2^1 + 0 \times 2^0$	$= 1 \times 4 + 0 \times 2 + 0 \times 1$	$= 4 + 0 + 0$

base 16

The hexadecimal system is used to represent groups of four binary digits. The *hexadecimal*, or *base 16*, system is based on 16 digits: 0 through 9, and the letters A through F representing 10 through 15 respectively. Each place represents a power of sixteen. For example, the hexadecimal number 1F represents the sum $1 \times 16^1 + 15 \times 16^0$. Some decimal numbers and their hexadecimal equivalents are:

Decimal	Binary	Hexadecimal	Base 16 Equivalent	
0	0000 0000	0	$= 0 \times 16^0$	$= 0 \times 1$
10	0000 1010	A	$= 10 \times 16^0$	$= 10 \times 1$
25	0001 1001	19	$= 1 \times 16^1 + 9 \times 16^0$	$= 1 \times 16 + 9 \times 1$
30	0001 1110	1E	$= 1 \times 16^1 + 14 \times 16^0$	$= 1 \times 16 + 14 \times 1$

ASCII and EBCDIC

ASCII (American Standard Code for Information Interchange) and EBCDIC (Extended Binary Coded Decimal Interchange Code) are two other digital coding schemes. Unlike Unicode, ASCII and EBCDIC are not large enough to support Asian and other languages that use a different alphabet.

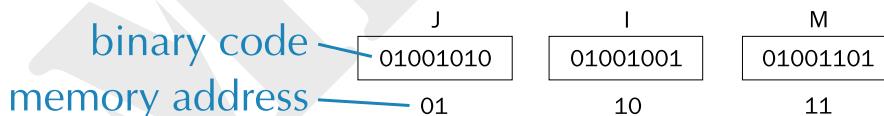
For clarity, a non-base 10 number should have the base subscripted after the number. For example, to show the difference between 100 in base 10 and 100 in base 2 (which represents 4), the base 2 number should be written as 100_2 .

Every letter of an alphabet (Latin, Japanese, Cherokee, and so on) and symbols of every culture (=, @, ½, and so on) have been given a representation in a digital code called Unicode. *Unicode* uses a set of sixteen 1s and 0s to form a 16-bit binary code for each symbol. For example, the uppercase letter V is Unicode 00000000 01010110, which can be thought of as the base 10 number 86 (86_{10}). Lowercase v has a separate code of 00000000 01110110, or 11810.

Storing Data in Memory

Computer memory is measured in bytes. For example, a computer might have 512MB of RAM. In computers and electronics *MB* stands for *megabytes* where mega represents 2^{20} or 1,048,576 bytes and *GB* stands for *gigabytes*, which is 2^{30} or 1,073,741,820 bytes.

Data stored in memory is referred to by an address. An *address* is a unique binary representation of a location in memory. Therefore, data can be stored, accessed, and retrieved from memory by its address. For data to be addressable in memory, it must usually be at least one byte in length. For example, to store JIM in memory each character is converted to Unicode and stored in two bytes of memory with each memory location designated by its address:



Because JIM is a character string, it will probably be stored in adjacent memory addresses.

words

Bits grouped in units of 16 to 64 (2 to 8 bytes) are called *words*. Data stored in a word is also located by an address. The size of a word depends on the computer system.

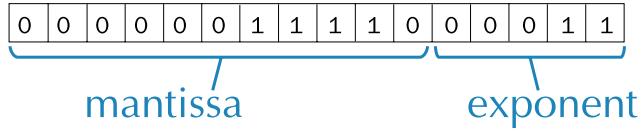
overflow error

The binary representation of an integer number is usually stored in four bytes of memory. Because an integer is stored in four bytes, the range of integers that can be stored is -2,147,483,648 to 2,147,483,647. An *overflow error* occurs when the number of bits that are needed to represent the integer is greater than the size of four bytes.

real numbers

Real numbers, also called *floating point numbers*, are numbers that contain decimal points. The binary representation of a real number is usually 4 to 8 bytes of memory. The binary number 111.10 is equivalent to the real decimal number 7.5 and is stored in memory as the binary number 0.11110×2^3 . In this form, the bits that represent the *mantissa* (fractional part) are stored in one section of a word and the *exponent*, in this example 3 (11_2), is stored in another section of the word:

**mantissa
exponent**



roundoff error

The overflow problem discussed for integers can also occur in real numbers if the part of the word storing the exponent is not large enough. A *roundoff error* occurs when there are not enough bits to store the mantissa.

What is a File?

File Size Limitations

File size can be decreased or compressed using a compression program, such as WinZip. This technique is often used to accommodate storage device and e-mail account limitations.

A **file** is related data stored on a persistent media. A file can be an application (program) or the product of an application. For example, a word processor application is used to create document files. As another example, a digital camera is used to create photo files. A file is stored on a persistent media so that it is retained even after the computer or computerized device is turned off. A file can be used over and over again whenever the data it stores is needed.

A file is really just 1s and 0s because it is stored in binary code. Computers are programmed to translate bytes and words into symbols. Depending on the file type, these symbols are either human-readable or computer-readable after translation. Human-readable files are called *text files*, and computer-readable files are called *binary files*. Simple files, such as a text document, can be measured *kilobytes*, for example 64K. The K comes from the word *kilo* and represents 2^{10} or 1,024. Therefore, a 64K file uses 65,536 bytes (64×2^{10}) of storage.

Extensions

Common extensions include:

- .xls - Excel file
.class - Compiled Java file
.java - Java file
.zip - compressed file
.gif - GIF image file
.bmp - Bitmap graphic

File types are distinguished by the *extension* that comes after the file name. An application adds a unique extension to the files it creates. For example, MyResume.doc is a document file type. A DOC file is a binary file created by Microsoft Word. Executables are EXE files and are also binary files. A file named TestData.txt is a plain text file. A TXT file contains only letters, numbers, and common symbols readable by humans. *Folders* are used to organize commonly related files.

Binary files are more complex than text files and often contain data for photos, formatted text, spreadsheets, sound, and so on. The disadvantage of binary files is that they require another application to interpret the contents. A binary file may have content similar to:

TIP The original form the file is saved in is referred to as the native format.

ÿýñU_ÿýþ}9UTýÿ-÷)J]I_ñyÑßÿÿý ÿ×_ÿ÷Äöÿ
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ÿþ

A binary file is computer-readable

Storage Devices

Storage devices use a persistent media to maintain files. These devices, which are also referred to as *drives*, *mass storage*, and *auxiliary storage*, can be categorized in three ways:

- internal or external
- removable or permanent media
- magnetic, optical, or solid state technology

Internal devices are drives mounted inside the PC case. These devices can include hard disk, CD/DVD, disk, tape, Zip, and Jaz drives. Except for the Iomega® RRD (Removable Rigid Disk) system, which uses a removable media, hard drives typically have permanently installed disks that are not accessible from outside the PC case. Other devices have an external slot for removable storage media.

External devices have a stand-alone drive housing and connect to a computer's USB port with a cable. USB (Universal Serial Bus) is a standardized technology with data transfer rates up to 480 Mbs. As many as 127 devices can be connected to a single port with USB hubs.

External drives offer the advantage of portability because they can be easily moved to other computers that support the technology. External devices include hard disk, RRD, CD/DVD, diskette, tape, Zip, and Jaz drives. Except for the hard disk drive, these drives have removable media.

Ultra-portable devices include keychain, watch, mini drive, and mouse storage to name just a few. These external devices are small and easy-to-use, but currently more expensive than comparable storage devices that are larger in size. Most ultra-portable devices, including the keychain and mini drive, have storage media attached directly to a USB plug that is connected to a USB port. The watch and mouse storage devices use a cable with a USB plug to connect to a USB port. The watch has a short cable and USB plug hidden in the band. The mouse storage device requires a longer cable so that it can also function as a pointing device.

Storage device technologies determine the media, size, and portability of a device. Magnetic technology uses a mechanical drive with tiny electromagnetic heads for reading and writing data to media. The media required with magnetic technology is a disk, usually made of aluminum or Mylar®, coated with iron oxide. The disk is either encased in hard plastic (floppy diskette and Zip) or several disks, called platters, are sealed in a case (Jaz, RRD, and hard disk). A data signal sent through the heads in the drive magnetize a bit of the media in one direction to store a 1 and in the other direction to store a 0.

Optical technology uses a drive with a laser and an optoelectronic sensor. The media required with optical technology is a compact disc made of polycarbonate plastic. A CD-R (CD-Recordable) disc is used for storing files. CD-Rs are coated with a reflective organic compound and then sealed with a plastic layer to protect the reflective layer from scratches. The laser in the drive is focused on a bit of the CD-R to darken, or "burn," the organic compound to store a 1. The areas of the CD-R left unburned are read as bits storing a 0.

Firewire

Using the IEEE 1394 standard, a FireWire port allows devices to quickly transfer large amounts of data (greater than 400Mbs). FireWire is often used for digital video cameras and sometimes external hard drives because of the amount of data associated with these devices. FireWire devices can be daisy-chained together, which means one device is connected to another's FireWire port and that device is connected to another and so on. FireWire also supports isochronous mode for real-time data transfer.

Tera, Peta, Exa

As more and more data is stored electronically, file sizes become very large and require storage devices with very large capacities. TB (terabyte) is 2^{40} bytes or 1 trillion bytes, petabyte (PB) is 2^{50} bytes or 1,024 terabytes, and EB (exabyte) is 2^{60} bytes or 1,024 petabytes. Devices with TB storage capacities are gradually coming into use, especially for database files.

Another application of optical technology is the *DVD drive*, which uses a DVD-R disc, similar to a CD-R. The DVD-R (Digital Video Disc-Recordable) can store much more data than a CD-R because of the precision used in manufacturing the drive and the DVD-R itself. Bits are much smaller and stored much more closely together on the DVD-R.

Solid state technology allows for the smallest, most portable storage devices because the technology requires no moving parts. The media is Flash memory, which consists of a grid with two tiny transistors at each cell. Each cell corresponds to a bit. Applying a charge to a cell stores a 0, while applying a stronger charge stores a 1. The grid of transistors is encased in hard plastic and is very small. Some devices can store 2MB or more within a package thinner and smaller than a quarter. Slightly larger media can store gigabytes of data. Encased media is often directly attached to a USB plug for use with a computer, or simply has conductive material imprinted so the media can slide into a digital camera slot.

Magnetic technology allows for storage devices that range in capacity from 1.44MB (a floppy diskette) to many gigabytes (hard disk drives with many platters). Optical technology includes CDs that can store about 700MB of data, while DVDs can store at least 4GB of data. Solid-state devices store from 64KB of data to many gigabytes.

Storage media can be very sensitive. Care should be taken to avoid damaging files:

- Never attempt to open a case containing a disk.
- Keep magnetic media away from magnets.
- Handle CD/DVDs by the center hole or by the edges.
- Never bend CD/DVDs or other flexible media.
- Store CD/DVDs in a jewel case or sleeve to prevent scratches.
- Keep media away from moisture and extreme temperatures.

Storage Media

The capacity of storage media varies. For example, a disk has a storage capacity of 1.44 MB, a CD has a storage capacity of 650 MB, and a DVD has a storage capacity of over 4GB.

Intranet, Extranet, Internet

An *intranet* is a network that is used by a single organization, such as a corporation or school, and is only accessible by authorized users. The purpose of an intranet is to share information. However, a firewall is also used to lock out unauthorized users. A *firewall* is a network security system that prevents unauthorized network access.

An *extranet* extends an intranet by providing various levels of accessibility to authorized members of the public. For example, a corporation may extend their intranet to provide access to specific information, such as their ordering system, to registered customers.

The largest and most widely accessed network is the *Internet*, a worldwide network of computers that is not controlled by any one organization. The Internet has had an undeniable impact on modern society because it allows users worldwide to communicate in a matter of seconds.

History of the Internet

The Internet evolved from ARPANET, a network created in the late 1960s by the Department of Defense's ARPA (Advanced Research Projects Agency), and the theory of open architecture networking.

The Internet is actually numerous networks all linked together through routers. A *router* is a device that connects different network technologies. Networks connected to routers use *TCP/IP* (Transmission Control Protocol/Internet Protocol) software to communicate.

Computers on the Internet are either servers or clients. The client is sent information from a server. The client/server structure of the Internet is called *interactive* because the information accessed is a result of selections made by the user. For example, a computer with just minimal software for accessing the Internet is a client. The client user selecting options from the Internet is receiving the information from a server, a computer with additional software and files that is also connected to the Internet.

Telecommunications

TIP Access to the Internet requires telecommunications and the use of an Internet Service Provider (ISP).

TIP In a wireless network, a router/wireless access point is typically connected by a cable to a cable or DSL modem.

Telecommunications is the transmitting and receiving of data. Data can be in various forms including voice and video. Telecommunications requires a modem or adapter and a line or cable. The speed of data transmission (sending) and receipt (receiving) is measured in *Kbps* (thousands of bits per second) or *Mbps* (millions of bits per second). Numerous telecommunications options are available, which vary in speed and cost:

- A **conventional modem** uses standard telephone lines to convert analog signals to digital data. A conventional modem is a 56 Kbps modem, which transmits data at 28.8 Kbps and 36.6 Kbps, and receives data at 56 Kbps. Home computers sometimes use a conventional modem.
- A **DSL** (Digital Subscriber Line) modem uses standard telephone lines with data transmission up to 640 Kbps. Data receipt is from 1.5 Mbps to 9 Mbps. A DSL (Asymmetric DSL) is the most common form used.
- A **cable modem** transmits data through a coaxial cable television network. Data transmission is from 2 Mbps to 10 Mbps and data receipt is from 10 Mbps to 36 Mbps.
- **Leased/Dedicated lines** are used by many businesses and schools for Internet access. They allow for a permanent connection to the Internet that is always active. The cost of a leased line is usually a fixed monthly fee. A T-1 carrier is a type of leased line that transmits data at 1.544 Mbps.
- **ISDN** (Integrated Services Digital Network) is a digital telephone network provided by a local phone company. ISDN is capable of transmitting and receiving data at up to 64 Kbps. ISDN requires the use of an ISDN terminal adapter instead of a modem.

Internet Services: Web, E-mail, and Mailing Lists

World Wide Web

web browser

Internet services include the World Wide Web, e-mail, and mailing lists. The *World Wide Web* (WWW), also called the *Web* is the most widely used Internet service. The Web can be used to search and access information available on the Internet. A *web browser* application, such as Microsoft Internet Explorer, provides a graphical interface to present information in the form of a website:



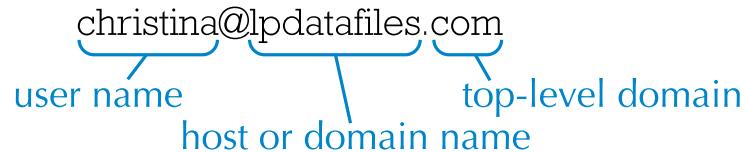
Blog

Blog is short for weblog and is a type of website where users can post entries in a journal format.

A web page that is part of the New York Times website

Another widely used Internet service is *e-mail* or *electronic mail*, which is the sending and receiving of messages and computer files over a communications network, such as a LAN (Local Area Network) or the Internet. E-mail can be received in a matter of seconds, even if the recipient is located half way around the world.

An e-mail address is required in order to send and receive e-mail messages. E-mail addresses are provided when you sign up with an ISP or an online service. A typical e-mail address is similar to:



Instant Messaging

Instant messaging is a communication tool that allows for real time or immediate text-based communication.

E-mail software is also required for sending and receiving e-mail messages. Examples of e-mail software include Outlook, Outlook Express, and Eudora. Browser-based e-mail only requires a web browser and is available through sites such as Yahoo! and Hotmail.

E-mail Protocols

POP3 is an e-mail protocol that connects to an e-mail server to download messages to a local computer.

IMAP is an e-mail protocol that connects to an e-mail server to read message headers and then the user selects which e-mail messages to download to a local computer.

HTTP is used as an e-mail protocol when a web page is used to access an e-mail account.

Spam

Along with personal and business messages, most people also receive a lot of "junk e-mail" or spam. Most e-mail software includes features to filter and block messages from specific senders.

Certain rules should be followed when composing e-mail messages

- Use manners. Include "please" and "thank you" and also properly address people you do not know as Mr., Ms., Mrs., Dr., and so on.
- Be concise.
- Be professional, which includes using the proper spelling and grammar.
- Re-read a message before it is sent. Always fill in the To box last to avoid sending a message before it is complete.

E-mail messages are not private. An e-mail message goes through several mail servers before it reaches the recipient, making it easily accessible for others to read. Therefore, sending e-mail messages requires following a certain etiquette:

- Send messages through your account only.
- Use appropriate subject matter and language.
- Be considerate of other people's beliefs and opinions.

When sending e-mail at work or school, it is important to remember that employers and school administrators have the right to read any e-mail messages sent over the corporate or school network, as well as the right to track online activity.

A *mailing list server* is a server that manages mailing lists for groups of users. Two mailing list servers are Listserv and Majordomo. Often users subscribe to mailing lists for discussion purposes. When a subscriber posts a message to a mailing list server, every subscriber receives a copy of the message. Subscribers are identified by a single name or e-mail address.

Finding Information on the Web and Downloading Files

Search Engines

A search engine usually works by sending out an agent, such as spider. A spider is an application that gathers a list of available web page documents and stores this list in a database that users can search by keywords.

When displaying information, search engines often show "Sponsored Sites Results" first. These are sites that contain the information being searched for but have paid the search engine to list their sites at the top of the list.

A *search engine* is a program that searches a database of web pages for keywords and then lists hyperlinks to pages that contain those keywords. Commonly used search engines include:

- Yahoo!** (www.yahoo.com)
- Google** (www.google.com)
- MSN** (www.msn.com)
- AOL** (www.aol.com)
- Excite** (www.excite.com)
- Ask Jeeves** (www.ask.com)
- Overture** (www.overture.com)
- Lycos** (www.lycos.com)
- WebCrawler** (www.webcrawler.com)
- FAST Search** (www.alltheweb.com)
- About.com** (www.about.com)
- AltaVista** (www.altavista.com)
- Looksmart** (www.looksmart.com)

A search engine can be queried to display specific web pages. *Search criteria* can include single words or phrases that are then used by the engine to determine a match. A *match* is a web page that contains the search criteria. Surrounding phrases with quotation marks finds web pages that contain the entire phrase. The more specific the search criteria, the better the chance the information will be found.

Most searches yield far too many matches to be useful. Limiting the number of matches to a reasonable number can usually be accomplished by using Boolean logic in the search criteria:

- The + (plus sign) is used in search criteria to limit a search to only Web pages that contain all of the specified words. For example, a search for florida +hotel or florida hotel returns only links to pages containing both words. AND can be used in place of + in most search engines.
- OR can be used in most search engines to find Web pages that contain any one of the words in the criteria. For example, the criteria florida OR hotel returns links to pages containing either of the words.
- The – (minus sign) is used to exclude unwanted Web pages. For example, the search for shakespeare –play returns hyperlinks to pages containing the word shakespeare, but eliminates pages that also contain the word play. NOT can be used in place of – in most search engines.

Some search engines provide a *subject tree*, or *web directory*, which is a list of sites separated into categories. The term subject tree is used because many of the categories “branch” off into subcategories. These subcategories allow the user to narrow down the subject and display a list of appropriate hyperlinks, which are at the lowest level of the tree.

Information on a website is sometimes in the form of a downloadable file. *Downloading* is the process of copying a file from a website to the user’s computer. For example, virus definitions can be downloaded from a antivirus software company’s website and software updates can be downloaded from the software company’s website. When a file is downloaded, the user specifies where the file should be saved on the local computer. Files should only be downloaded from known, authentic websites since downloadable files are often associated with viruses.

If information from a website is to be referenced or quoted in a report, essay, or other document, a citation must be used to give credit to the original author and allow the reader to locate the cited information. A widely accepted form for citation is published by the Modern Language Association (MLA) in its publication *MLA Handbook for Writers of Research Papers, Fourth Edition*.

In general, a citation for material located at a website should look similar to:

Author's Last Name, First Name MI. Site Title. Access date.
Organization name. <URL>.

A citation of a personal website could look similar to:

Rawlings, Julie. Home page. 23 Dec. 2006. <<http://www.lpdatafiles.com/jrawlings/index.htm>>.

Boolean Logic

Boolean logic uses three logical operators:

AND locates pages that include both words

OR locates pages that include one word or the other or both

NOT locates pages that include the first word, but not the second word

A boolean expression always evaluates to TRUE or FALSE with pages that match the search condition evaluating to TRUE.

TIP Just because a file is available on a website for download does not mean that it is legal to download the file. Downloading copyrighted files that have not been made freely available is a violation of copyright law.

MLA

A citation of an article in an online magazine could look similar to:

Schiffman, Paula. "Making Vinegar at Home." *Vinegar Monthly*. 4 May 2006. <<http://www.lpdatafiles.com/vinegarassoc/journal.asp>>.

A citation of a posting to a discussion list could look similar to:

Cruz, Anthony. "Are Orchestras Going Downhill?" online posting. 10 Oct. 2006. Tuscon Annual Ballet Conf. <<http://www.lpdatafiles.com/tuscontoes/downhill.txt>>.

Internet Privacy Issues

The growth of the Internet has caused additional concerns about personal privacy. Searching for information on the Internet is not as anonymous as it might seem.

The collection of data about consumers visiting a website is a marketing technique known as *online profiling*. When a commercial website is visited, information about the user may be collected using various methods such as cookies or web beacons.

A *cookie* is a text file created by the server computer when a user enters information into a website. The cookie file is then stored on the user's computer and accessed each time the user visits that website. Cookies are often created when online purchases are made. Although cookies can only store information that the user has selected or entered, their use has raised concerns over privacy issues.

Web beacons, also called *web bugs* or *pixel tags*, are tiny, transparent graphics located on web pages or in e-mail messages that are used in combination with cookies to collect data about web page users or e-mail senders. Usually the monitoring is done by an outside advertising company. The information a web beacon collects includes the IP address of the computer, the URL being visited, the time the web page was viewed, the type of browser being used, and the cookie file.

Before providing a company with personal information through a website, check the site's privacy policy. A *privacy policy* is a legally binding document that explains how any personal information will be used.

The Internet has opened up access to many files that were previously inaccessible. To protect both the privacy of an individual and the accuracy of data stored about individuals, several laws have been passed:

- The **Electronic Communications Privacy Act of 1986 (ECPA)** makes it a crime to access electronic data without authorization. It also prohibits unauthorized release of such data.
- The **Electronic Freedom of Information Act of 1996 (E-FOIA)** requires federal government agencies to make certain agency information available for public inspection and is designed to improve public access to agency records by making more information available online.
- The **Children's Online Privacy Protection Act of 1998 (COPPA)** requires commercial websites that collect personal information from children under the age of 13 to obtain parental consent.

NET Act

The NET (No Electronic Theft) Act of 1997 closed a loophole in the law which allowed copyrighted material to be given away on the Internet without any legal penalty.

Encryption

Encryption is the process of translating data into a code that is not readable without the key to the code. Encryption prevents unauthorized access to the data. Data that is encrypted is referred to as cipher text.

Internet Filtering Software

Many schools and organizations install Internet filtering software to block offensive material.

- The **Safety and Freedom through Encryption Act of 1999 (SAFE)** gives Americans the freedom to use any type of encryption to protect their confidential information.

Other laws have been passed that may invade the privacy of some to protect the safety of others. For example, the **Provide Appropriate Tools Required to Intercept and Obstruct Terrorism (PATRIOT) Act of 2001** gives law enforcement the ability to monitor individual's e-mail and web activity.

Internet Acceptable Use Policy

Internet content, unproductive use, and copyright have prompted many schools and businesses to develop an Acceptable Use Policy or Internet Use Agreement. Acceptable Use Policies typically contain rules similar to:

- Use appropriate language.
- Do not reveal personal address or phone numbers.
- Do not access, upload, download, or distribute inappropriate materials.
- Do not access another user's account.
- Use of the network for private business is prohibited.
- Only administrator installed software may be used on the computers. Adding, deleting, or modifying installed software is not permitted.

The Social and Ethical Implications of Computer Use

information age

ergonomics

The society in which we live has been so profoundly affected by computers that historians refer to the present time as the *information age*. This is due to our ability to store and manipulate large amounts of information (data) using computers. As an information society, we must consider both the social and ethical implications of our use of computers. By ethical questions we mean asking what are the morally right and wrong ways to use computers.

Ergonomics is the science that studies safe work environments. Many health-related issues, such as carpal tunnel syndrome and computer vision syndrome (CVS) are related to prolonged computer use.

Power and paper waste are environmental concerns associated with computer use. Suggestions for eliminating these concerns include recycling paper and printer toner cartridges and turning off monitors and printers when not in use.

Employee monitoring is an issue associated with computers in the workplace. It is legal for employers to install software programs that monitor employee computer use. As well, e-mail messages can be read without employee notification.

Identity Theft

Identity theft is a growing crime where personal information is stolen electronically in order to make fraudulent purchases or loans.

As discussed in a previous section in the chapter, the invasion of privacy is a serious problem associated with computers. Because computers can store vast amounts of data we must decide what information is proper to store, what is improper, and who should have access to the information. Every time you use a credit card, make a phone call, withdraw money, reserve a flight, or register at school, a computer records the transaction. These records can be used to learn a great deal about you—where you have been, when you were there, and how much money was spent. Should this information be available to everyone?

Computers are also used to store information about your credit rating, which determines your ability to borrow money. If you want to buy a car and finance it at a bank, the bank first checks your credit records on a computer to determine if you have a good credit rating. If you purchase the car and then apply for automobile insurance, another computer will check to determine if you have traffic violations. How do you know if the information being used is accurate? The laws listed below have been passed to help ensure that the right to privacy is not infringed by the improper use of data stored in computer files:

- The **Fair Credit Reporting Act of 1970** gives individuals the right to see information collected about them for use by credit, insurance, and employment agencies. If a person is denied credit they are allowed to see the files used to make the credit determination. If any of the information is incorrect, the person has the right to have it changed. The act also restricts who may access credit files to only those with a court order or the written permission of the individual whose credit is being checked.
- The **Privacy Act of 1974** restricts the way in which personal data can be used by federal agencies. Individuals must be permitted access to information stored about them and may correct any information that is incorrect. Agencies must insure both the security and confidentiality of any sensitive information. Although this law applies only to federal agencies, many states have adopted similar laws.
- The **Financial Privacy Act of 1978** requires that a government authority have a subpoena, summons, or search warrant to access an individual's financial records. When such records are released, the financial institution must notify the individual of who has had access to them.

Protecting Computer Software and Data

copyright

As society becomes more and more reliant on digital information, copyright and exposure to malicious code have become two important issues among computer users. *Copyright* is protection of digital information. Copyright infringement is the illegal use or reproduction of data (text, pictures, music, video, and so on). Laws, such as the NET Act (No Electronic Theft Act) of 1997, protect against copyright infringement. There have been several well-known cases of high penalties for individuals guilty of copyright infringement.

TIP It is usually legal to make one backup copy of a purchased software program.

Copyright infringement includes duplication of computer software when copies are being used by individuals who have not paid for the software. This practice is called *piracy* when illegal copies are distributed. Developing, testing, marketing, and supporting software is an expensive process. If the software developer is then denied rightful compensation, the future development of all software is jeopardized. Therefore, it is important to use only legally acquired copies of software, and to not make illegal copies for others.

Malicious code comes in many forms and is delivered in many ways. A virus, a Trojan horse, and an Internet worm are three forms of malicious code. They can appear on a system through executable programs, scripts, macros, e-mails, and some Internet connections. One devastating effect of malicious code is the destruction of data.

virus

A *virus* is a program or series of instructions that can replicate without the user's knowledge. Often a virus is triggered to run when given a certain signal. For example, a virus might check the computer's clock and then destroy data when a certain time is reached. A virus is easily duplicated when the file is copied, which spreads it to other computers.

Trojan horse

A *Trojan horse* program appears as something else, usually a program that looks trustworthy. Running the program runs the malicious code and damages files on the computer. A *worm* is a program that is able to reproduce itself over a network. *Worms* are a threat because of the way they replicate and use system resources, sometimes causing the system to shut down.

antivirus programs

Malicious code has become so widespread that software called *antivirus programs* must be installed on computers and networks to detect and remove the code before it can replicate or damage data. Precautions can also be taken to prevent damage from malicious code:

- Update antivirus software. An antivirus program can only detect the viruses, Trojan horses, and worms it is aware of. Antivirus programs have a web link for updating the virus definitions on the computer containing the antivirus program.
- Do not open e-mail attachments without scanning for malicious code. One estimate states that 80% of virus infection is through e-mail.

crackers, hackers

Newspapers have carried numerous reports of *crackers*, or *hackers*, gaining access to large computer systems to perform acts of vandalism. This malicious act is illegal and can cause expensive damage. The Electronic Communications Privacy Act of 1986 specifically makes it a federal offense to access electronic data without authorization. Networks usually include a firewall, which is a combination of hardware and software, to help prevent unauthorized access.

The willful destruction of computer data is no different than any other vandalizing of property. Since the damage is done electronically the result is often not as obvious as destroying physical property, but the consequences are much the same. It is estimated that computer crimes cost billions of dollars each year.

phishing

Phishing is the act of sending an e-mail to a user falsely claiming to be a legitimate business in an attempt to trick the user into revealing personal information that could be used for crimes such as identity theft. The Communications Privacy Act of 1986 specifically makes it a federal offense to access electronic data without authorization. Networks usually include a firewall, which is a combination of hardware and software, to help prevent unauthorized access.

The Ethical Responsibilities of an IT Professional

IT Careers

The growth of computers, the Internet, and the Web have created many new job opportunities in the IT field. IT careers include data-entry operator, systems analyst, programmer, computer engineer, and technical support technician.

An *IT* (information technology) professional has responsibilities that relate to system reliability. System reliability involves installing and updating appropriate software, keeping hardware working and up-to-date, and maintaining databases and other forms of data. Governments, schools, and employers rely on IT professionals to maintain their computer systems.

In addition to ensuring system reliability, an IT professional must take responsibility for the ethical aspects of the career choice. For example, IT professionals involved in creating software must ensure, as best he or she can, the reliability of the computer software. This means the ethical responsibility of the IT professional includes using the appropriate tools and methods to test and evaluate programs before distribution. A special cause for concern is the increased use of computers to control potentially dangerous devices such as aircraft, nuclear reactors, or sensitive medical equipment.

IT professionals must also consider the impact they have on computer users. Web users for example often rely on data from websites providing real-time information. The information displayed is determined with a program written using a 4GL or other language that accesses a database. The IT professionals involved in such a project have the ethical responsibility to possibly millions of individuals for ensuring, as best they can, accurate data retrieval.

As capable as computers have proven to be, we must be cautious when allowing them to replace human beings in areas where judgement is crucial. As intelligent beings, we can often detect that something out of the ordinary has occurred which has not been previously anticipated and then take appropriate actions. Computers will only do what they have been programmed to do, even if it is to perform a dangerous act.

Chapter Summary

A desktop computer and its components are designed to fit on or under a desk. Mobile computers include notebooks, tablets, handhelds, smart phones, and wearables. A computer must run operating system (OS) software in order to control processing and peripherals, run application software, and control input and output, among other tasks.

A network is a combination of hardware and software that allows computers to exchange data and share software and devices, such as printers. Networks are classified by their size, architecture, topology, and protocol. Network users should use netiquette.

A programming language is a set of words, codes, and symbols that allows a programmer to communicate with the computer. Programming languages can be classified as low-level and high-level languages. Low-level programming languages include machine language and assembly language. High-level programming languages have English-like instructions and are easier to use than machine language. High-level programming languages include Fortran, C, Basic, COBOL, and Pascal.

The electrical circuits on an IC have one of two states, off or on. Therefore, the binary number system (base 2), which uses only two digits (0 and 1), was adopted for use in computers. Our most familiar number system is the decimal or base 10 system. The binary number system is a base 2 system and the hexadecimal system is base 16. Every letter of an alphabet (Latin, Japanese, Cherokee, and so on) and symbols of every culture (=, @, ½, and so on) have been given a representation in a digital code called Unicode.

Computer memory, file sizes, and storage device capacities are measured in bytes. In computers and electronics MB stands for megabytes, GB stands for gigabytes, and K stands for kilobytes.

The binary representation of an integer number is usually stored in four bytes of memory. Real numbers are numbers that contain decimal points and the binary representation of a real number is usually 4 to 8 bytes of memory.

A file is related data stored on a persistent media. A file is really just 1s and 0s because it is stored in binary code. Computers are programmed to translate bytes and words into symbols. File types are distinguished by the extension that comes after the file name. Folders are used to organize commonly related files.

Storage devices use a persistent media to maintain files. These devices, which are also referred to as drives, mass storage, and auxiliary storage, can be categorized as internal or external, as removable or permanent media, and as magnetic, optical, or solid state technology.

An intranet is a network that is used by a single organization and is only accessible by authorized users. A firewall is a network security system that prevents unauthorized network access. An extranet extends an intranet by providing various levels of accessibility to authorized members of the public. The largest and most widely accessed network is the Internet. The most widely used Internet service is the World Wide Web, also called the Web. Other Internet service include e-mail and mailing lists.

Telecommunications is the transmitting and receiving of data. Telecommunication options include a conventional modem, a DSL modem, a cable modem, leased/dedicated lines, and ISDN.

A search engine is a program that searches a database of web pages for keywords and then lists hyperlinks to pages that contain those keywords.

Search criteria is used by the search engine to determine a match. Limiting the number of matches to a reasonable number can be accomplished using Boolean logic in the search criteria. Some search engines also provide a subject tree, or web directory.

Information found at a website should be evaluated for accuracy. There are guidelines for citing electronic material on the Internet. The primary purpose of a citation is to give credit to the original author and allow the reader to locate the cited information.

The growth of the Internet has caused concerns about personal privacy. Online profiling, cookies, and web bugs are all areas of concern. Before providing personal information through a website, check the site's privacy policy. To protect an individual's privacy, several laws have been passed. Concerns about Internet content, unproductive use, and copyright have prompted many schools and businesses to develop an Internet Use Agreement.

Historians refer to our present time as the information age. The potential for the use of computers to invade our right to privacy has prompted legislation to protect individuals. Piracy is the illegal act of duplicating software without permission. A virus is a computer file that erases data and can cause considerable damage.

Working as an IT (information technology) professional includes taking responsibility for the ethical aspects of a career choice. IT professionals must also consider the impact they have on computer users.

Vocabulary

Address A unique binary representation of a location in memory.

Address bus Carries memory addresses that indicate data storage locations.

ALU (Arithmetic Logic Unit) The part of the CPU that handles arithmetic and logic operations.

Antivirus program Software installed on computers and networks to detect and remove viruses.

Applications software Program written to perform a specific task.

Base unit Housing that contains the motherboard, CD-RW/DVD drive, disk drive, and hard disk drive.

Binary number system Number system used by computers that uses only digits 0 and 1. Also called base 2.

Bit (BInary digit) A single 0 or 1 in binary code.

Bus A central network cable. Also a set of circuits that connect the CPU to other components.

Bus topology A physical LAN topology that uses a single central cable to attach each node directly.

Byte A group of 8 bits.

Cable modem A modem that transmits data through a coaxial cable television network.

Cache High-speed memory used to store frequently used data so that it can be quickly retrieved by an application.

Client A computer that is sent information from a server computer.

Client/server network A type of network that consists of a group of computers, called clients connected to a server computer.

Clock rate The speed at which a CPU can execute instructions, measured in megahertz or gigahertz.

Compiler A program that converts an entire program into machine code before the program is executed.

Control bus Carries control signals.

Conventional modem A modem that uses standard telephone lines to convert analog signals to digital data.

Cookie Text file created by the server computer when a user enters information into a website.

Copyright Protects a piece of work from reproduction without permission from the work's author.

CPU (Central Processing Unit) Processes data and controls the flow of data between the computer's other units. Also contains the ALU. Located on the motherboard.

Cracker Person who accesses a computer system without authorization.

Cross-platform connectivity The ability of one type of PC to link to and share data with a different type of PC.

Dedicated line See Leased line.

Device driver One type of utility program.

Downloading The process of copying a file from a website to the user's computer.

DSL (Digital Subscriber Line) modem A modem that uses standard telephone phone lines. ADSL is the most common form used.

E-mail (electronic mail) The sending and receiving of messages and electronic files over a communications network such as a LAN or the Internet.

Environment A computer's hardware and software configuration. Also referred to as platform. Environment types include desktop, multiuser, network, handheld, distributed, multiprocessing, and multitasking.

Ergonomics The science that studies safe work environments.

Extension Added after a file name to distinguish file types.

Extranet An extended intranet that provides various levels of access to authorized members of the public.

Expansion boards Circuit boards that connect to the motherboard to add functionality to the computer.

File A collection of related data stored on a lasting medium.

Firewall A network security system that prevents unauthorized network access.

Folder Used to organize commonly related files.

Gigabytes (GB) Approximately one billion bytes.

Gigahertz (GHz) Billion of cycles per second.

Hacker *see* Cracker.

Handheld computer A mobile computing device.

Hardware The physical components of the computer, such as the monitor and system unit.

Hexadecimal system Number system based on 16 digits. Also called base 16.

High-level programming languages Third generation programming languages that have English-like instructions.

Hub A communication device that joins communication lines at a central location on the network.

Information age Present time characterized by increasing dependence on the computer's ability to store and manipulate large amounts of information.

Input device Device used to enter data and instructions into the computer.

Integrated circuits (ICs) A silicon wafer with intricate circuits etched into its surface and then coated with a metallic oxide that fills in the etched circuit patterns. Also called a chip.

Interactive Information accessed as a result of selections made by the user.

Internet The largest and most widely accessed network.

Interpreter A program that translates and executes an instruction before moving on to the next instruction in the program.

Intranet A network that is used by a single organization and only accessible by authorized users.

ISDN (Integrated Services Digital Network) A digital telephone network provided by a local telephone company.

IT (Information Technology) A term that encompasses all aspects of computer-related technology.

Kbps Thousands of bits per second.

Kilobytes (K) Approximately a thousand bytes.

LAN (Local Area Network) A network used to connect devices within a small area.

Leased line A telecommunication option used for a permanent connection to the Internet that is always active.

Logical topology Refers to the way in which data is passed between the nodes on a network.

Low-level programming languages First and second-generation programming languages including machine language and assembly language.

Mailing list server A server that manages mailing lists for groups of users.

Magnetic technology Storage device technology that uses a mechanical drive with tiny electro-magnetic heads for reading and writing data to media.

Match A web page that contains the search criteria.

Mbps Millions of bits per second.

Megabytes (MB) Approximately one million bytes.

Megahertz (MHz) Million of cycles per second.

Memory-resident A program that is always in memory.

Minus sign (-) Used in search criteria to exclude unwanted web pages.

Modern Language Association (MLA) Organization that publishes standards used for citations.

Motherboard The main circuit board inside the base unit.

Netiquette The etiquette that should be followed when using a network.

Network A combination of software and hardware that allows computers to exchange data and to share software and devices, such as printers.

Network architecture The structure of a network.

Network interface card A circuit board that goes into a computer or other device in a LAN.

Network operating system Software that allows users and devices to communicate over a network.

Node A location on the network capable of processing information, such as a computer or a printer.

Notebook A portable, lightweight computer.

Object-oriented programming (OOP) An approach to programming where modules are created that can be used over and over again.

Online profiling A marketing technique that collects online data about consumers.

Operating system Software that allows the user to communicate with the computer. Types include multiuser, multiprocessing, multitasking, multithreading, or real time.

Optical technology Storage device technology that uses a drive with a laser and optoelectronic sensor.

Output device A device used to convey processed data.

Overflow error An error that occurs when the number of bits that are needed to represent the integer is greater than four bytes.

Overwrites Updates an original file with changes.

Peer-to-peer network A type of network that does not have a server.

Peripheral device A device attached to a PC.

Phishing The act of sending an e-mail to a user falsely claiming to be a legitimate business in an attempt to trick the user into revealing personal information that could be used for crimes such as identity theft.

Piracy Illegally copying or distributing software.

Plus sign (+) Used in search criteria to limit a search to only those web pages containing two or more specified words.

Port Used to attach a peripheral device to a computer.

Privacy policy A legally binding document that explains how any personal information will be used.

Programming languages A set of words, codes, and symbols that allows a programmer to communicate with the computer.

RAM (Random Access Memory) Memory that temporarily stores data and instructions. Also called primary or main memory.

Real numbers Numbers that contain decimal points.

Real time Occurs immediately.

Ring topology A physical LAN topology where each node is connected to form a closed loop.

ROM (Read Only Memory) Memory that stores data and is a permanent part of the computer.

Roundoff error An error that occurs when there are not enough bits to hold the mantissa.

Router A device that connects different network technologies.

Search criteria A single word or phrase that is used by the search engine to match web pages.

Search engine A program that searches a database of web pages for keywords and then lists hyperlinks to pages that contain those keywords.

Secondary memory Any type of storage media.

Server A computer used to manage network functions such as communication and data sharing.

Smartphone Cellular phone that is able to send and receive e-mail messages and access the Internet.

Solid state technology Storage device technology that requires no moving parts.

SRAM (Static Random Access Memory) High-speed memory referred to as cache.

Star topology A physical LAN topology where each node is attached to a hub.

Storage devices Devices that use persistent media to maintain files. Also referred to as drives, mass storage, and auxiliary storage.

Subject tree A list of sites separated into categories.

Tablet PC A computer designed similar to a pad of paper.

TCP/IP (Transmission Control Protocol/Internet Protocol) Software used by networks connected to routers to communicate.

Telecommunications The transmitting and receiving of data.

Topology The physical or logical arrangement of the nodes on a network.

Transmission media The media that joins the nodes on a network to enable communication.

Trojan horse Malicious code in the form of a program that appears as something else, usually a program that looks trustworthy.

Ultra-portable devices Storage devices, such as keychains, that are small and easy-to-use.

Unicode A digital code that uses a set of sixteen 1s and 0s to form a 16-bit binary code for each symbol.

Utility program Program run by the operating system to manage input and output, read and write to memory, manage the processor, maintain system security, and manage files and disks.

Virus A program that is designed to reproduce itself by copying itself into other programs stored on a computer without the user's knowledge.

WAN (Wide Area Network) A network used to connect computers over large geographical distances.

Wearable computer A mobile computing device that is incorporated into clothing, eyewear, wristwear, and other wearables.

Web *See* World Wide Web.

Web beacon A tiny, transparent graphic located on a web page used to collect data about the web page user. Also called a web bug or pixel tag.

Web browser Interprets an HTML document to display a web page.

Web directory *See* Subject tree.

Wireless network A type of network that does not require the use of cables.

Word Bits grouped in units of 16 to 64.

World Wide Web The most widely used Internet service. Used to search and access information available on the Internet.

Worm Program that is able to reproduce itself over a network.

Review Questions

1. a) What is hardware?
b) What are input and output devices used for?
c) What is a peripheral device?
2. List and describe five components found on the motherboard.
3. Describe the flow of data between the components of a computer, starting with input.
4. a) Describe one difference between operating system software and applications software.
b) Describe three different types of operating systems.
c) What does environment refer to?
5. What is a utility program? Give an example.
6. List four types of mobile computing devices.
7. What is a stylus used for?
8. Describe one type of wearable computer.
9. Why is cross-platform connectivity important to many computer users?
10. a) What is the difference between low and high level programming languages?
b) List three high-level programming languages.
c) What is the difference between a compiler and an interpreter?
d) List an advantage of using an object-oriented programming language.
11. List four benefits of using a network.
12. a) What are the two common size classifications for networks?
b) What size classification is used to connect devices over large geographical distances?
13. a) What is a network operating system?
b) What does a network environment refer to?
14. Describe two common network architecture models.
15. a) What does physical topology refer to?
b) What is a node?
c) Which topology uses a hub?
d) Which topology connects each node to form a closed loop?
e) What is the difference between physical and logical topology?
16. List three netiquette rules.
17. Explain why the binary number system was adopted for use in computers.
18. a) What is the decimal equivalent of 111_2 ?
b) What is the decimal equivalent of $2C_{16}$?
19. What is Unicode?
20. a) How many bytes of data can 512 MB of RAM store?
b) How many bytes of data can a 40 GB hard drive store?
21. What are bits grouped in units of 16 to 64 called?
22. When would an overflow error occur?
23. a) What are real numbers?
b) When would a roundoff error occur?
24. a) What is the difference between a text file and a binary file?
b) Explain how an extension distinguishes file types.
c) Why would organizing files into folders be considered a good practice?
25. List three ways storage devices can be classified and give an example of a storage device in each category.
26. Describe three storage device technologies.
27. List four rules that should be followed to avoid damaging files stored on disks or CD/DVDs.
28. a) What is the difference between an intranet and an extranet?
b) Who controls the Internet?

29. List three telecommunications options.
30. a) If a business needed constant access to the Internet, what type of connection line would be a good choice? Why?
b) What does a cable modem use instead of analog phone lines?
31. What is the most widely used Internet service?
32. a) What is e-mail?
b) List one benefit of e-mail over standard mail.
c) Write your e-mail address and label the parts of the address.
d) What are the two requirements for sending and receiving e-mail messages?
e) List one example of a browser-based e-mail site.
33. a) Explain why sending an e-mail message should be thought of the same as sending a postcard.
b) List three examples of e-mail etiquette.
34. a) What is a search engine?
b) List three commonly used search engines.
c) Which search engine do you prefer to use, and why?
d) What is search criteria?
e) What is a match?
35. Write search criteria to locate web pages that contain the following information:
a) restaurants in Los Angeles
b) art museums in Boston
c) auto repair jobs in Montreal, Canada
d) mosquitoes and bees, but not ants
e) the English author Jane Austen
f) the phrase *to each his own*
g) George Washington and John Adams, but not Thomas Jefferson
h) travel to Ireland, but not Dublin
36. List a search engine that provides a subject tree.
37. a) What is downloading?
b) Why should files only be downloaded from authentic sites?
38. a) List four questions to answer when evaluating a website source.
b) Why is it necessary to cite sources?
c) On August 2, 2006 you accessed a posting on the Clewiston Kite Surfing discussion list at <http://www.lpdatafiles.com/kitesurf/color.txt>. The posting was made by Tara Perez on the topic of kite colors. Write a citation for a research paper that quotes Tara's posting.
39. What is online profiling?
40. What is a cookie?
41. a) What is a web beacon?
b) Who usually monitors the information collected by web beacons?
42. Locate a website's privacy policy and document its contents.
43. Name and briefly describe one law that helps protect the privacy of an individual.
44. a) List three reasons why many schools have developed an Acceptable Use Policy.
b) List an example of a rule that typically appears on an Acceptable Use Policy.
45. What can you do if you are turned down for credit at a bank and believe that the data used to deny credit is inaccurate?
46. a) What is necessary for a federal government authority to access an individual's financial records?
b) What must a financial institution do after releasing an individual's records?
47. a) What is copyright infringement?
b) Why is computer piracy such a concern to software developers?
c) What is a computer virus?
d) Describe phishing.
48. What ethical responsibilities does an IT professional have?

True/False

49. Determine if each of the following are true or false. If false, explain why.
- a) A computer must have an operating system installed before application software can be installed.
 - b) FireWire and USB are types of ports.
 - c) A peer-to-peer network has a server.
 - d) A LAN's logical topology is always the same as its physical topology.
 - e) The hexadecimal system is a base 2 system.
 - f) Computer memory is measured in bytes.
 - g) The most widely accessed network is the Internet.
 - h) A conventional modem transmits data faster than a cable modem.
 - i) E-mail messages are private.
 - j) Information found at a website is always accurate.
 - k) The present time is referred to as the industrial age.
 - l) Ergonomics is the science that studies safe work environments.
 - m) A virus is a harmless computer game.

Exercises

Exercise 1

In this exercise you will research your classroom computer network by answering a series of questions:

- a) Is your computer network a LAN or a WAN?
- b) List one device that is shared on the network.
- c) Locate the cable that plugs into the network interface card on your workstation.
- d) What type of physical topology is used?
- e) What type of transmission media is used?
- f) What network protocol is used?
- g) What operating system is used?
- h) Describe your workstation's environment.
- i) What telecommunication option is used?
- j) Does the school have an intranet?
- k) List four rules on the school's Internet Use Agreement.

Exercise 2

In this exercise you will assess the input and output devices you have access to.

- a) List the input devices accessible on the classroom network.
- b) List the output devices accessible on the classroom network. List advantages and disadvantages associated with each accessible output device.

Exercise 3

In this exercise you will organize your existing files. You may need to refer to the appropriate operating system chapter on www.lpdatafiles.com to complete this exercise.

- a) Examine the files you currently have saved on your computer. Use the appropriate operating system command to rename any files that do not have descriptive names.
- b) Use the appropriate operating system commands to organize your existing files into appropriate folders.

Exercise 4

A good friend has been diagnosed with Carpal Tunnel Syndrome and would like you to find out as much as you can about the injury and possible treatments.

- a) Conduct a search on the Internet using at least two search engines to find three web pages that have information about Carpal Tunnel Syndrome.
- b) Write a brief description of the injury.
- c) In a second paragraph, write about possible treatments for the injury.
- d) Write a citation for each source.

Exercise 5

Expand on the information presented in this chapter by researching one of the following topics:

- Network Protocols
- Operating Systems
- The History of the Internet
- Evolution of Programming Languages
- Identity Theft

- a) Use the Internet, magazines, and books to find at least three sources of information.
- b) Write a two page report that summarizes your research.
- c) Write a citation for each source.

Exercise 6

In this exercise you will research and compare the advantages and cost of obtaining Internet access through three different telecommunication options.

- a) Use the Internet and newspapers to find information about Internet service providers (ISPs).
- b) Compare the costs and the advantages of at least three different telecommunication options.
- c) Write a one paragraph conclusion that explains what telecommunication option would be the best choice.
- d) Write a citation for each source.

Exercise 7

In this exercise you will further research emerging technologies and find real-life examples of how these technologies have impacted individuals and businesses.

- a) Use the Internet, magazines, and books to learn more about at least three emerging technologies. Look specifically for information on how these emerging technologies impact individuals and businesses. For example, speech recognition technology greatly impacts those individuals who must rely on voice input rather than keyboard input for a PC.
- b) Write a two-page report that summarizes the impact of and lists several functions of the emerging technologies you have researched.
- c) Write a citation for each source.

Exercise 8

Many computer viruses have been associated with e-mail attachments.

- a) Conduct a search on the Internet to find information about a virus associated with an e-mail attachments.
- b) Write a one-paragraph description of the virus. Include details, such as the damage caused by the virus and steps necessary to remove the virus.
- c) Write a citation for each source.

Exercise 9

You have decided to investigate computer programming as a possible career path.

- a) Conduct a search on the Internet using at least two search engines to find three appropriate bachelor degree programs.
- b) List each program location (college name), the number of credits required to finish the degree, and the tuition cost per credit or per course.

Exercise 10

In this exercise you will investigate mailing lists.

- a) Join an appropriate computer-related mailing list.
- b) Participate on the mailing list as a learner.
- c) Contribute to the mailing list content.

Chapter 2

Applets and Web Programming

This chapter discusses Web programming by introducing HTML and JavaScript. Java applets are also introduced.

The World Wide Web

The most widely used Internet service is the World Wide Web (WWW), also called the Web. The *Web* is used to search and access information available on the Internet. A *web browser application*, such as Internet Explorer provides a graphic interface to present information from a website. A *website* consists of a series of related web pages. For example, a CNN web page looks similar to:

Browsers

Commonly used web browser applications include Internet Explorer, Netscape, Opera, Firefox, Amaya, and Safari.

website



A web page displayed in a web browser

HTML hypertext

Most web pages are created using HTML (HyperText Markup Language) and other code. *HTML* is a markup language that is well suited for the Web because it supports hypertext and multimedia. *Hypertext* is a database



Tim Berners-Lee
1955 –

Tim Berners-Lee is credited with creating the World Wide Web. Berners-Lee now heads a non-profit group, the W3C (World Wide Web Consortium), which sets technical standards for the Web.

TIP HTML is not a case sensitive language.

TIP A tag should not have any spaces between the opening bracket and the element or slash.

TIP A web server is a computer that communicates with a web browser over the Internet using HTTP.

Internet Explorer

To view an HTML document saved on a local computer in Internet Explorer, select File → Open. Next, select Browse to navigate to the location where the HTML document is saved.

system where objects, such as text and images, can be linked. *Multimedia* includes images, video, audio, and Java applets, which can be embedded in an HTML document.

Millions of people all over the world are able to view and author web content because the World Wide Web Consortium (W3C) continuously develops standards for the Web. These standards include HTML standards to ensure that HTML documents display similarly in different browsers and across different platforms. They have also developed Web accessibility standards for those with disabilities.

HTML

HTML uses a set of codes, called *tags*, to “mark up” plain text so that a browser application, such as Internet Explorer, knows how to interpret the text. A tag is comprised of an *element* inside angle brackets (<>). For example, <title> is called the title tag, where title is the element. Tags affect the text they surround, and are usually paired to indicate the start and end of an instruction. A slash (/) before the element indicates the end of an instruction, such as </title>.

A web page with one line of text will be displayed when the HTML document below is opened in a browser:

```
<html>
<head>
<title>An example HTML document</title>
</head>
<body>
<p>Hello world!</p>
</body>
</html>
```

Text marked up with <title> and </title> is displayed in the title bar of the browser window. The text Hello world! is marked to be displayed as a paragraph (<p> and </p>) in the body of the browser window (<body> and </body>). When viewed in Internet Explorer, the HTML tags are interpreted sequentially and the document appears similar to:



A web browser is used to access and view HTML documents that have been published to a web server. The web browser first interprets the URL to identify the location of the page on the Web and then interprets the HTML document to display a web page in the browser window. HTML documents saved on a local computer can also be viewed in a browser.

Creating an HTML Document

TIP In Internet Explorer, the HTML associated with a displayed web page can be viewed by selecting View → Source.

Validating HTML

HTML documents can be validated to ensure they are meeting W3C standards at the <http://validator.w3.org> website.

In order to validate an HTML document, a DTD (document definition tag) must be included as the first line of an HTML document. For example, to check to see if an HTML document meets HTML 4.01 standards, include the tag:

```
<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01//EN"
"http://www.w3.org/TR/html4/stict.dtd">
```

HTML documents are plain text files and can be created using any text editor, such as Notepad, or by using a word processor. In general, the structure of an HTML document should be similar to:

```
<html>
  <head>
    <title>document title</title>
  </head>
  <body>
    content
  </body>
</html>
```

An HTML document contains pairs of tags

The html, head, title, and body tags are called *document tags*:

- The `<html>` tag tells the browser that the file contains HyperText Markup Language.
- The `<head>` tag defines the section that contains information about the document, including its title. This section will not be displayed as part of the document content.
- The `<title>` tag marks the document title. The title section must be within the head section. The document title should be descriptive and meaningful because it is displayed in the title bar of the browser's window and is also used when the user adds the document to the browser's Favorites list.
- The `<body>` tag defines the body section, which contains the document's content. All content must be enclosed in the appropriate tags. For example, on the previous page, the content is marked as a paragraph.

HTML documents are *free-form*, which means that spaces and blank lines generally have no effect on how the document is interpreted. Therefore, the document:

```
<html><head><title>An example HTML document</title>
</head>
<body> <p>Hello world!</p></body></html>
```

Poorly structured HTML document

displays exactly the same as the HTML document on the previous page. However, editing a poorly structured document can be time-consuming and error-prone.

An HTML document is saved with a lowercase, descriptive file name. The file name should not contain any spaces and the `.htm` extension needs to be added. If using a word processor to save the file, be sure to save the file in TXT format.

saving an HTML document

Review: hello_world.htm

Create a properly structured HTML document that displays “My name is *Name*. Hello world!”, replacing *Name* with your name. Include the title “First HTML Document”. View the HTML document in a browser.

Review: Computer Viruses Website – part 1 of 6

Create a properly structured HTML document that displays the text “Computer Viruses.” Include the title “Computer Viruses”. Save the document as `computer_virus.htm` and view the HTML document in a browser.

JavaScript

Java vs JavaScript

JavaScript is similar to the Java programming language, but it is a separate language.

TIP JavaScript is case sensitive.

JavaScript Files

Scripts can also be written as a separate JavaScript file, which is saved with a `.js` extension, and then referenced in the script tag.

Scripts are used to add dynamic content to an HTML document and consist of a list of commands that execute without user interaction. Scripts are written in a scripting language, such as JavaScript. *JavaScript* is a scripting language that is interpreted by a browser’s built-in JavaScript engine.

In an HTML document, JavaScript code is written as a script block between `<script>` and `</script>` tags. Scripts are typically found in the head section, but can be placed anywhere in an HTML document. Displaying a message in an alert dialog box is one form of dynamic content that can be added to an HTML document using a script:

```
<head>
<title>JavaScript Greeting</title>
<script type="text/javascript">
// Display a greeting
alert("Hello World!");
</script>
</head>
```

- The `type` attribute in the `script` tag specifies which scripting language is used to define the script.
- `//` is used to add a single line comment that explains the script.
- `alert()` displays an alert dialog box with the specified text message.
- A semicolon is used to end each JavaScript statement.

The script above is interpreted when the HTML document is loaded:



JavaScript can also be used to prompt the user for information:

```
<head>
<title>JavaScript User Name</title>
<script type="text/javascript">
//initialize a variable with a null value
var name = null;
// Ask user for their name
name = prompt("Please enter your first name", " ");
//Greet the user
alert("Welcome " + name);
</script>
</head>
```

TIP JavaScript terminology is similar to Java terminology which is explained throughout the text.

- A variable called `name` is initialized to represent the user's name.
- `prompt()` displays the specified message in a prompt dialog box. The empty string, " ", after the message indicates the prompt box is to be blank when the dialog box is first displayed. When the user enters their name, it is assigned it to the variable `name`.
- The text message and variable are joined by a +.

The script above generates output similar to:



Review: welcome.htm

Create an HTML document that contains a script block that prompts the user for their full name and then displays the message "Welcome to our site *Full Name*", replacing *Full Name* with the user's name, in an alert dialog box.

Review: Computer Viruses Website – part 2 of 6

Modify `computer_virus.htm` to include a script block that prompts the user for their first name when the page loads and then displays "Ready to Learn About Computer Viruses *Name*?", replacing *Name* with the user's name, in an alert dialog box.

Using Scripts to Enhance a Website

Static websites can be enhanced by the dynamic nature of scripts. For example, JavaScript can be used to define the default message that is displayed in the status bar of the browser window:

```
<script type="text/javascript">
// Display a status bar message
window.defaultStatus="Hello World";
</script>
```

The script above is interpreted when the HTML document is loaded, and displays a message in the status bar of the browser window:



Note that priority is given to system messages, such as when a page is loading.

JavaScript can also be used to display the current date and time on a web page:

```
<head>
<title>JavaScript Current Date</title>
<script type="text/javascript">
// Display the current date
var now = new Date();
document.write(now);
</script>
</head>
```

- A new date object called `now` is created. Objects are discussed in chapter 4.
- `document.write` is used to display output on the web page:

Sat Jan 22 23:16:24 EST 2005

A screenshot of a web browser window. The content area displays the text "Sat Jan 22 23:16:24 EST 2005".

Web applications are often programmed to display differently depending on the user's browser, platform, and whether Java is enabled. These settings can be detected using JavaScript:

```
<head>
<title>JavaScript Setting Detector</title>
<script type="text/javascript">
// Detect the browser
var browser = navigator.appName;
// Detect the platform
var platform = navigator.platform;
// Detect Java enabled
var JavaCheck = navigator.javaEnabled();
alert(browser + "\n" + platform + "\n" + "Java is enabled: " +
+ JavaCheck);
</script>
</head>
```

- `navigator.appName` detects the browser name.
- `navigator.platform` detects the operating system.

Java Enabled

Users can enable and disable Java in their web browser's Internet options settings.

- `navigator.javaEnabled()` detects whether Java is enabled and returns a value of true or false.
- `\n` creates a new line.

The script will generate output similar to:



Review: Computer Viruses Website – part 3 of 6

Modify `computer_virus.htm` to display “Computer Viruses” in the status bar of the browser window and to display the current time and date on the first line of the web page.

Review: System Check – part 1 of 2

Create an HTML document that detects the browser, platform, and whether the browser is Java enabled. Display the output in an alert dialog box.

Java Applets

TIP This section provides a brief overview on writing Java applets. You may want to revisit this section after becoming more familiar with the Java programming language.

A *Java applet* is a small Java application that is embedded in an HTML document and run in a browser window. When a browser interprets a document that contains a Java applet, the program files are downloaded onto the user's machine and then the browser's Java interpreter runs the applet. Java applets are well suited for the Web because they are able to run on different hardware and across different platforms. Applets are secure because they do not have the ability to read or write to files on a user's computer.

Numerous applets can be downloaded from the Web and embedded in an HTML document to add dynamic content. Applets take various forms, such as animated banners, stock ticker tapes, photo cubes, and animated video clips. Original applets can also be created.

Creating Java Applets

TIP Visit 1pdatafiles.com for specific information about different Java compilers.

An applet is created in a Java compiler, such as JCreator. The Java code for the applet is saved with a `.java` extension and then compiled to convert the Java code to bytecode. The bytecode is saved with a `.class` extension.

The code below is for a basic applet that paints the message “My first Java applet” at a specific screen location:

```
/*
 * Example _ Applet.java
 */

import java.awt.*;
import java.applet.*;

public class Example _ Applet extends Applet {

    String message;

    public void init() {
        message="My first Java applet";
    }

    public void paint(Graphics g) {
        g.setColor(Color.blue);
        g.drawString(message, 50, 60 );
    }
}
```

TIP The example applet uses the `Applet` class, which is part of the `java.applet` package, and the `Graphics` class, which is part of the `java.awt` package.

TIP Packages, classes, and methods are explained in Chapter 3.

- The two `import` statements indicate which Java packages are used.
- A class is used to define an applet and extend the `Applet` class. Applets are always an extension of the `Applet` class.
- The `init()` method is used to initialize variables to starting values. The variable `message` is assigned the text string, “My first Java applet”.
- The `paint()` method is used to paint text, shapes, and graphics onto the screen. In this example, the `paint()` method defines a `Graphics` object named `g`.
- The `setColor()` method sets the text color.
- The `drawString()` method draws the message on the screen at the specified coordinates.

Sun’s Java Software Development Kit (SDK) includes a tool called an `appletviewer`, which can be used to interpret, execute, and test an applet. When executed, the example applet above will appear similar to:



Drawing Shapes and Adding Color

Original applets can be created to draw colorful images. The applet below illustrates how shapes can be drawn and filled and how the background and foreground colors are set:

```
/*
 * Drawing Shapes and Changing Color Example
 */
import java.awt.*;
import java.applet.*;

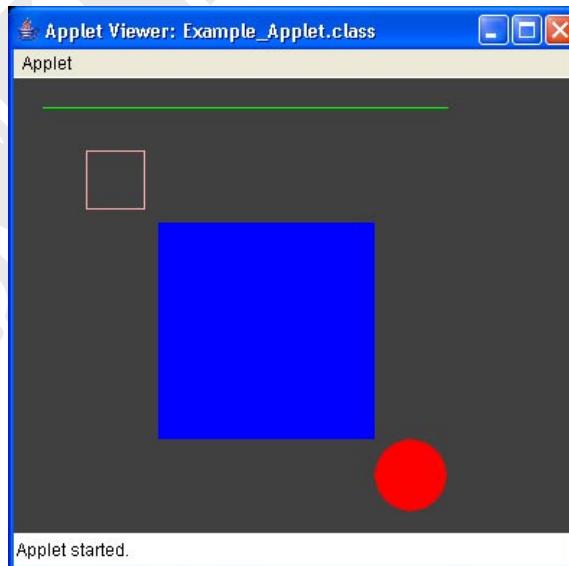
public class Shapes _ Color extends Applet {

    public void paint(Graphics g) {
        setBackground (Color.darkGray);
        g.setColor(Color.pink);
        g.drawRect(50, 50, 40, 40);
        g.setColor(Color.blue);
        g.fillRect(100, 100, 150, 150);
        g.setColor(Color.green);
        g.drawLine(20, 20, 300, 20);
        g.setColor(Color.red);
        g.fillOval(250, 250, 50, 50);
    }
}
```

Predefined Colors

Predefined colors include black, blue, cyan, gray, darkGray, lightGray, green, magenta, orange, pink, red, white, and yellow.

When executed, the applet looks similar to:



The different shapes require specified coordinates. For example:

- `drawLine (x1, y1, x2, y2)` Paints a line from coordinates (x1, y1) to (x2, y2).
- `drawOval (x, y, width, height)` Paints an oval with the upper left corner at position (x, y) with the specified width and height.
- `drawRect (x, y, width, height)` Paints a rectangle with the upper left corner at position (x, y) with the specified width and height.

- `drawArc (x, y, width, height, startAngle, arcAngle)` Paints an arc with the upper left corner at position (x,y) with the specified width, height, starting angle, and arc angle.

Review: Hot Air Balloon



This review requires a Java compiler. Experiment with drawing shapes and adding color by creating an applet that paints a picture of a hot air balloon on the screen. Compile the applet and view it in the appletviewer.

Accessibility

In response to the ADA (Americans with Disabilities Act), enacted in 1990, the W3C has developed guidelines called the Web Accessibility Initiative (WAI). These guidelines call for alternative text to be provided for any content on a web page that is not text.

`<object>` Tag

The `<object>` tag allows for multimedia resources, such as video and audio, to be embedded in an HTML document. When interpreting an `<object>` tag, the browser determines if another application, such as the Windows media player, is needed to display the object.

The `<object>` tag can also be used to embed a media player console in an HTML document using Microsoft ActiveX controls.

TIP Parameters typically need to be specified for applets downloaded from the Web.

Placing an Applet in an HTML Document

An applet is embedded in an HTML document within the `<applet>` and `</applet>` tags. The tags can surround an alternative text message that will be displayed if the applet cannot run in the browser:

```
<html>
  <head>
    <title>Embedding an Applet</title>
  </head>

  <body>
    <applet code = "FirstApplet.class" width = "300" height = "60">
      You are unable to view the applet.
    </applet>
  </body>
```

The `<applet>` tag has three required attributes:

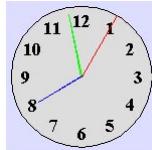
- `code="name"` specifies the name of the applets to run
- `width="value"` specifies the width for the applet display in pixels
- `height="value"` specifies the height for the applet display in pixels

Applet Parameters

Parameters allow users to specify custom values to use in a Java applet. In an HTML document, parameter information is specified in a `<param>` tag, which requires two attributes, name and value. For example, the HTML document below specifies a specific image file, `scenery.gif`, to use in the applet.

```
<body>
  <applet code = "AppletParam.class" width = "300" height = "60">
    <param name = "image" value = "scenery.gif">
    You are unable to view the applet.
  </applet>
</body>
```

Review: System Check – part 2 of 2



```
<applet code="JavaClock.class" width="150" height="150">
<param name="bgcolor" value="fffffff">
<param name="border" value="5">
<param name="ccolor" value="ddddd>
<param name="cfont" value="TimesRoman|BOLD|18">
<param name="delay" value="100">
<param name="hhcolor" value="0000ff">
<param name="link" value="http://java.sun.com/">
<param name="mhcolor" value="00ff00">
<param name="ncolor" value="000000">
<param name="nradius" value="80">
<param name="shcolor" value="ff0000">
</applet>
```

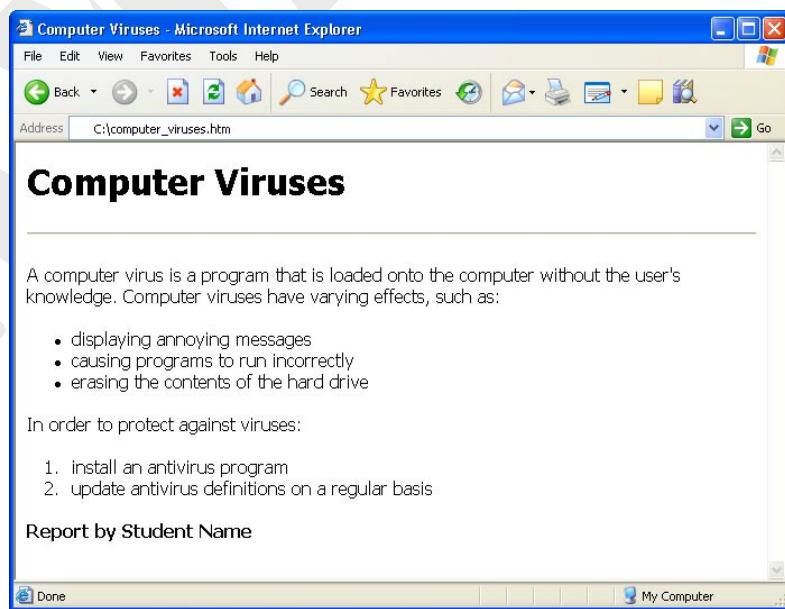
Save the modified System Check HTML document in the classes folder in the CLOCK website included in the data files for this text.

HTML Tags

HTML 4

The current version of HTML is HTML 4. HTML 4 is supported by newer browsers.

In addition to applets and scripts, a web page can contain text. For example, consider the following web page:



The HTML for the web page is shown below. The body section of the HTML document includes the content and tags that format the content:

```
<body>
<h1>Computer Viruses</h1>
<hr>
<p>A computer virus is a program that is loaded onto the computer without the user's knowledge. Computer viruses have varying effects, such as:</p>
```

```

<!--creates a bulleted list-->
<ul>
<li>displaying annoying messages</li>
<li>causing programs to run incorrectly</li>
<li>erasing the contents of the hard drive</li>
</ul>
<p>In order to protect against viruses:</p>
<!--creates a numbered list-->
<ol>
<li>install an antivirus program</li>
<li>update antivirus definitions on a regular basis</li>
</ol>
<h4>Report by Student Name</h4>
</body>

```

Browser Preferences

The formatting associated with heading tags varies between browsers and is dependent on the preferences set by the user.

There are six levels of headings, which are represented with tags `<h1>` through `<h6>`. Heading tags are used to emphasize enclosed text. Each heading level has specific formatting associated with it, which includes font size, bold text, and space above and below the heading. Heading 1 has the largest font size and is used to represent the most important information. Heading 6 has the smallest font size.

The `<hr>` tag places a horizontal rule (line) across the width of the browser window. This feature is used to divide the text in the browser window into sections for easier reading. The horizontal rule tag does not need to be paired.

attribute

HTML tags may also contain attributes. An *attribute* is placed in the start tag and set to a value that modifies the element. For example, the horizontal rule width attribute specifies the width of the line in the browser window as a percentage, `<hr width="50%">`. Other attributes of the `<hr>` tag include:

- `size="value"` specifies the thickness of the rule in pixels.
- `align="value"` specifies the rule alignment. The default alignment is center.

paragraphs

Text enclosed by `<p>` and `</p>` is a paragraph. Lines of paragraph text are automatically wrapped by the browser, and a blank line is added after each paragraph. To move a line of text within a paragraph to the next line, a break tag `
` is used. A break tag does not need to be paired.

comments

Comments are text used to explain and clarify HTML to the reader of an HTML document. They do not appear in a browser window. Comments start with an angle bracket, followed by an exclamation mark and two hyphens. At the end of the comment are two more hyphens and an ending bracket, `<!--comment-->`.

lists

Lists are used to organize information. Bulleted and numbered are two types of lists that can be created in an HTML document. A *bulleted list*, also called an *unordered list*, is used when each item is equally important. A *numbered list*, also called an *ordered list*, is used to show priority of importance.

Bulleted list tags include:

- ` ` defines the start and end of a bulleted list
- ` ` defines the start and end of an item

Numbered list tags include:

- ` ` defines the start and end of a numbered list
- ` ` defines the start and end of a list item

Review: Computer Viruses Website – part 4 of 6

Modify the body section of `computer_virus.htm` to include the content and tags shown on the two previous pages. View the HTML document in a browser.

Hyperlinks, Tables, and Images

The display of an HTML document can be further enhanced with hyperlinks, tables, and images. *Tables* are used to arrange data in an HTML document. Note the virus table:

The screenshot shows a Microsoft Internet Explorer window titled "Antivirus Program - Microsoft Internet Explorer". The address bar shows "C:\antivirus.htm". The main content area displays a heading "Checking for Viruses" followed by a paragraph about antivirus programs. Below this is a heading "Example Virus Threats" and a table with three rows. The table has two columns: "Virus" and "Threat". The data is as follows:

Virus	Threat
Worm MyDoom.p	Low
Worm Blueworm.D	Low
Worm Bagle.AI	Medium

Below the table is a small graphic of a hand holding a computer mouse over a keyboard. At the bottom of the page is a placeholder "Report by: Student Name".

The HTML for the web page is shown below:

```
<html>
<head>
<title>Antivirus Program</title>
</head>

<body>
<h2>Checking for Viruses</h2>
<p>A computer can be checked for <a href="computer_virus.htm">viruses</a> using an antivirus program. An antivirus program is a utility that scans a hard disk for viruses. If a virus is located, it will be removed by the antivirus program.</p>

<h2>Example Virus Threats </h2>
<table border="2" width="300" cellpadding="5">
```

```

<th>Virus</th>
<th>Threat </th>
<tr><td>Worm MyDoom.p</td>
<td>Low</td></tr>
<tr><td>Worm Blueworm.D</td>
<td>Low</td> </tr>
<tr><td>Worm Bagle.AI</td>
<td>Medium</td> </tr>
</table>

<h5>Report by: Student Name</h5>
</body>
</html>

```

The anchor tag () is used in an HTML document to mark text that is a link. The href attribute is set in the tag to the name of the linked document. For example, [digital cameras](digicam.htm).

TIP Visited hyperlinks are typically displayed as purple, underlined text in the browser window.

A *hyperlink*, also called a *link*, is text displayed in a browser window that can be clicked to display a different HTML document in the browser window. Hyperlinks are what make a hypertext system, such as the Web work. Hyperlinks are typically displayed as blue, underlined text in the browser window. Countless documents can all be linked, allowing the user to go from topic to topic, or browse HTML documents.

A table requires several tags for formatting:

- `<table> </table>` creates a table.
- `<th> </th>` creates a table header, which is a cell with bold, centered text.
- `<tr> </tr>` defines the start and end of a table row.
- `<td> </td>` defines the start and end of a table data cell.

The `<table>` tag attributes include:

- `border="value"` specifies the thickness of the cell border where value is in pixels.
- `cellpadding="value"` sets the amount of space between table cells where value is a number.
- `width="value"` specifies the width of a table where value is a number in pixels or a percentage of the document's width.

The display of an HTML document can also be enhanced with images. The `` tag inserts an image where file name is the file name of the graphic. Image files added to an HTML document should be GIF, JPG, or PNG format. The image tag does not need to be paired. Attributes of the `` tag include:

- `border="value"` specifies the size of the border around the image where value is a number in pixels.
- `alt="value"` specifies alternate text for the graphic where value is the alternative text.
- `height="value"` specifies the height of the image in pixels.
- `width="value"` specifies the width of the image in pixels.

GIF, JPG, PNG

GIF (Graphics Interchange Format) format is limited to 256 colors and best used for clip art or logos, JPG (Joint Photographic Expert Group) format supports millions of colors and is best used for photographs. PNG (Portable Network Graphic) format is a newer format only support by recent brower versions.

Review: Computer Viruses Website – part 5 of 6

Modify computer_virus.htm to make the text “antivirus program” a hyperlink to a document named antivirus.htm. Create the antivirus.htm document using the content and formatting shown in the HTML document in the “Hyperlinks, Tables, and Images” section. Note that the first paragraph links “viruses” to computer_virus.htm. The VIRUS.gif image file is a data file for this text. Test the hyperlinks in a browser window.

Style Sheets

A *style sheet* is used to define the type, paragraph, and page formats for an HTML document. Style sheets give HTML documents a consistent appearance because they override the browser settings that interpret how tags are displayed:



embedded style sheet

A style sheet can be embedded or linked. An *embedded style sheet* is defined within `<style type="text/css">` and `</style>` tags in the head section of the HTML document. The embedded style sheet for the web page above appears as:

```
<!--apply style sheet rules to the document-->
<style type="text/css">
h1 {color: #FF0000; text-align: center}
p {font-family: Georgia, "Times New Roman", Times, serif; font-size: 16 px; line-height: 18 px}
ul {font-family: Georgia, "Times New Roman", Times, serif; font-size: 14 px; line-height: 18 px}
ol {font-family: Georgia, "Times New Roman", Times, serif; font-size: 14 px; line-height: 18 px}
h4 {text-align : right}
</style>
```

linked style sheet

A *linked style sheet* is a separate file that is saved with a .css extension and applied using `<link rel="stylesheet" href "style.css" type="text/css">`, where `style.css` is the name of the style sheet.

Font Family Declarations

Font-family declarations indicate the first font that a browser should display, and then alternate fonts if the first is not installed on the user's computer.

Style sheets can include rules and classes, a linked style sheet can contain only rules. A *rule* modifies an HTML element and is comprised of a selector and declarations. The *selector* is the HTML element being redefined and the *declarations* are the formats to be applied. For example:

```
p { font-family: Georgia, "Times New Roman", Times, serif;  
    font-size: 16px;}
```

Style Sheet Rule

The rule above will automatically display paragraphs in 16 px Georgia. The font-family property can also be specified as generic font, such as serif, sans serif, or monospace and the font-size may be defined in points, pixels, inches, or centimeters (pt, px, in, cm).

class

A *class* is a set of declarations that can be applied to different tags. Class names begin with a dot (.). For example:

```
.para_with_space {  
    font-family: Georgia, "Times New Roman", Times, serif;  
    font-size: 14px;  
    line-height: 28px;  
}
```

Style Sheet Class

The class above can be applied to individual paragraphs to format the paragraph in 14px Georgia with a line-height of 28 px. For example:

```
<p class="para_with_space">Spyware is software that collects  
information without the user's knowledge. The information is  
usually for advertising purposes.</p>
```

hexadecimal

Text and background colors in an HTML document are specified using hexadecimal numbers. *Hexadecimal* is a base-16 numbering system that consists of the numbers 0 through 9 and the letters A through F. Color constants and corresponding hexadecimal values include:

Black (#000000)	Silver (#C0C0C0)
Gray (#808080)	White (#FFFFFF)
Maroon (#800000)	Red (#FF0000)
Purple (#800080)	Fuchsia (#FF00FF)
Green (#008000)	Lime (#00FF00)
Olive (#808000)	Yellow (#FFFF00)
Navy (#000080)	Blue (#0000FF)
Teal (#008080)	Aqua (#00FFFF)

text and background color

To change the background and text color of an HTML document, the HTML body element is modified in a style sheet rule:

```
body { background-color : #000000; color : #FFFFFF }
```

To change the text color of a selected tag, the appropriate HTML element is modified in a style sheet rule. For example:

```
h1 {color : #0000FF }
```

text alignment

HTML content is left aligned by default. To change the alignment of an entire HTML document, the HTML body element is modified in a style sheet rule:

```
body { text-align : center }
```

To change the alignment of certain parts of a document, modify the appropriate HTML element. For example, the Heading 1 tag is modified in a style sheet rule to be right aligned:

```
h1 {text-align : right }
```

Review: Computer Viruses Website – part 6 of 6

Modify computer_virus.htm to include an embedded style sheet with rules to format Heading 1 style in a red color, center aligned and Heading 4 style as right aligned. Also include rules to format paragraphs in Georgia, Times New Roman, Times, serif font-family in a font size of 16 pixels and a line height of 18 pixels and unordered, and ordered list tags in Georgia, Times New Roman, Times, serif font-family in a font size of 14 pixels and a line height of 18 pixels. Add an appropriate comment to the document.

Create a linked style sheet with the rules to format Heading 1 style in a navy color and Heading 4 style as right aligned. Link the style sheet to antivirus.htm. View the documents in a browser.

Chapter Summary

Most web pages are created using HTML (HyperText Markup Language) and other code. HTML is a markup language that is well suited for the Web because it supports hypertext and multimedia. HTML uses a set of codes, called tags, to “mark up” plain text so that a browser application, such as Internet Explorer, knows how to display the text in a browser window.

Scripts are used to add dynamic content to an HTML document. JavaScript is a scripting language that is interpreted by a browser’s built-in JavaScript engine. In an HTML document, JavaScript code is written as a script block between `<script>` and `</script>` tags.

A Java applet is a small Java application that is embedded in an HTML document within the `<applet>` and `</applet>` tags and run in a browser window. Applets can be downloaded from the Web and embedded in an HTML document to add dynamic content. Original applets can also be created. Parameters allow users to specify custom values to use in a Java applet. In an HTML document, parameter information is specified in a `<param>` tag.

The `<html>`, `<head>`, `<title>`, and `<body>` tags are called document tags. Other HTML tags introduced in this chapter include:

- the paragraph tag, `<p>`
- the break tag, `
`
- the heading tags, `<h1>` through `<h6>`
- the horizontal rule tag, `<hr>`
- the unordered list tag, ``
- the ordered list tag, ``
- the table tag, `<table>`
- the image tag, ``
- the anchor tag, `<a>`
- the comment tag, `<!--comment-->`
- the style sheet tag, `<style>`

Tags may also contain attributes. An attribute is placed in the start tag and set to a value that modifies the element.

Vocabulary

Attribute Used to modify the features of an element in an HTML tag.

Bulleted list A list that is used when each item is equally important:

Class A set of declarations that can be applied to different tags.

Comment Text used to explain and clarify HTML for a reader.

Declarations The formats to be applied in a style sheet rule.

Document tags The html, head, title, and body tags.

Element The part of an HTML tag placed inside angle brackets (<>). For example, <title> is called the title tag, where title is the element.

Embedded style sheet A style sheet defined with <style> and </style> tags in the head section of an HTML document.

Free-form Spaces and blank lines generally have no effect on how the document is interpreted. The format of an HTML document.

Hexadecimal A base-16 numbering system that consists of the numbers 0 through 9 and the letters A through F.

HTML (HyperText Markup Language) A set of tags that are used to “mark up” plain text so that a browser application knows how to display the text.

Hyperlink Text that can be clicked to display another HTML document. Also called a link.

Hypertext A database system where objects, such as text and images, can be linked.

Java applet A small Java application that is embedded in an HTML document and run in a browser window.

JavaScript A scripting language that is interpreted by a browser’s built-in JavaScript engine.

Link *see* hyperlink.

Linked style sheet A style sheet saved as a separate file with a .css extension and applied using a <link> tag.

Multimedia Images, video, audio, and Java applets embedded in an HTML document.

Numbered list A list that is used to show a priority of importance.

Ordered list *see* Numbered list.

Parameters Used to specify custom values to use in a Java applet.

Rule A line in a browser window for dividing content.

Scripts Used to add dynamic content to an HTML document. Scripts are written in a scripting language, such as JavaScript.

Selector The HTML element being redefined in a style sheet rule.

Style sheet Used to define the type, paragraph, and page formats for an HTML document.

Tables Used to arrange data in an HTML document.

Tag Comprised of an element inside angle brackets that is used to “mark up” plain text so that a browser application knows how to display the text.

Unordered list *see* Bulleted list.

Web Tool used to search and access information available on the Internet.

Web browser application Provides a graphic interface to present information in the form of a website.

Website Series of related web pages.

HTML Tags

`<a>` The anchor tag. Links text to another HTML document. Attributes include href.

`<applet>` The applet tag. Embeds an applet in an HTML document.

`
` The break tag. Moves a line of text within a paragraph to the next line.

`<!--comment-->` A comment tag. Explains and clarifies HTML to the reader.

`<h1>` through `<h6>` The heading tags. Emphasizes text.

`<head>` The head tag. Indicates information about the document, including its title.

`<hr>` The horizontal rule tag. Displays a line in the browser window. Attributes include width, align, and size.

`<html>` The HTML tag. Indicates that the file contains HTML.

`` The image tag. Inserts an image.

`` The list item tag. Defines the start and end of an item.

`<link>` The link tag. Links a style sheet.

`` The ordered list tag. Defines the start and end of a numbered list.

`<p>` The paragraph tag. Formats the content. Attributes include align.

`<script>` The script tag. Defines a script.

`<style>` The style sheet tag. Embeds a style sheet.

`<table>` The table tag. Creates a table.

`<title>` The title tag. Displays the document title in the title bar of the browser window. Must be in the head section of an HTML document.

`` The unordered list tag. Defines the start and end of a bulleted list.

Critical Thinking

1. a) What is the most widely used Internet service?
b) List two examples of web browsers.
 2. a) What is used to create most web pages?
b) Why is HTML well suited for the Web?
c) Why is it important for the W3C to develop Web standards?
 3. Why is the order of HTML tags and content important in an HTML document?
 4. a) List the four document tags.
b) Why is it important to properly structure an HTML document when HTML is a free-form language?
c) What rules are followed when saving an HTML document?
 5. a) Where are scripts placed in an HTML document?
b) How can scripts enhance a website?
c) Write a script to display "Good-bye" in an alert dialog box.
d) Write a script to display "Today's News" in the status bar of the browser window.
 6. a) What is a Java applet?
b) How is a Java applet interpreted by a web browser?
c) List two reasons why Java applets are well suited for the Web?
 7. The following HTML document has seven errors. What are they?
8. a) What does a style sheet define?
b) Why are style sheets used?
c) What is the difference between an embedded and a linked style sheet?
 9. What element is modified to change the background color or alignment of a web page?

True/False

10. Determine if each of the following are true or false. If false, explain why.
 - a) A website consists of a series of web pages.
 - b) Hypertext is a database system.
 - c) An HTML document must be published to a web server in order to be viewed in a web browser.
 - d) Spaces and blank lines generally have no effect on how an HTML document is interpreted.
 - e) HTML documents are saved with a TXT extension.
 - f) Scripts must be placed in the head section of an HTML document.
 - g) JavaScript is used to add dynamic content to an HTML document.
 - h) Java applets are interpreted on web servers.
 - i) Java applets can only run on a Windows platform.
 - j) Java applets have the ability to write files on a user's computer.
 - k) Java applets have to be compiled.
 - l) The anchor tag is used to create a hyperlink.
 - m) A rule modifies an HTML element.

```
<html>
<body>
<title>Operating Systems</title>
</body>

<head>
<!--adds a horizontal rule-->
<hr width is 50%>
<p>Every computer must have an operating system. Types of operating systems include:</p>
<ul>
<li>Windows</li>
<li>UNIX</li>
<li>Linux</li>
<li>OS/2</li>
</ul>
</head>
</html>
```

Exercises

Exercise 1 tourist_attractions.htm

Research tourist attractions in a particular city by using the Internet, magazines, and books and then create an HTML document that lists tourist attractions for a particular city. The HTML document should include:

- a comment with your name
- an appropriate title
- the city name in Heading 1 format
- “Tourist Attractions” in Heading 2 format
- a horizontal rule
- at least five tourist attractions, each displayed in a bulleted list
- a style sheet with at least three rules
- a script

Exercise 2 sports_report.htm

Create an HTML document that documents recent school sports related news. The HTML document should include:

- a comment with your name
- appropriate titles formatted with heading tags
- a horizontal rule
- at least three news stories
- an image
- a style sheet with at least three rules
- a script

Exercise 3 applet.htm

Create an “Applet Help” HTML document that documents the steps to create an original applet or download an applet and embed the applet in an HTML document. Display an example of an original applet or a downloaded applet from <http://java.sun.com/openstudio/index.html> on the HTML document.

Exercise 4

[electronic_portfolio.htm](#)

A portfolio is a collection of work that clearly illustrates effort, progress, and achievement of knowledge and skills. An electronic portfolio stores and presents portfolio content in a digital format such as a website. Create linked HTML documents that presents your contact information, academic history, work and volunteer experience, and accomplishments.

Exercise 5

[computer_history.htm](#)

Research the history of computers by using the Internet, magazines, and books and then collaborate in small groups to create linked HTML documents that outline key events in computer history by decade. Describe at least five key events for the 1970s, 1980s, 1990s, and 2000s. Use a style sheet to format the HTML documents.

Exercise 6

[html_reference.htm](#)

Create an “HTML Reference” document that lists HTML tags, describes the tag, and provides corresponding examples. Research and include at least three HTML tags not covered in this chapter. The www.w3c.org website documents HTML tags.

Exercise 7

[copyright.htm](#)

Research copyright laws and issues as they pertain to digital information. Present your research in the form of at least two linked HTML documents. Include an additional linked HTML document to cite the sources used using an established method, such as MLA or APA style.

Exercise 8

[technology_report.htm](#)

Create an HTML document that reviews a recently released software application or hardware device. List the product specifications and target market for the product. Include your opinion on whether you think the product will be successful or useful.

Exercise 9

[interview.htm](#)

Interview a local web programmer about software, tools, and knowledge they feel are important when creating websites. Document your interview. In small groups, share your interview documentation.

SAMPLE

Chapter 3

Introducing Java

Java, developed by Sun Microsystems, is a widely used high-level programming language. One reason for its wide-spread use is the ability to create platform-independent applications. This chapter introduces Java, OOP terminology, code conventions, and program design.

Why Program in Java?

Object-oriented programming (OOP) evolved out of the need to develop complex programs in a systematic, modular approach. The OOP approach allows programmers to create modules that can be used over and over again in a variety of programs. These modules group related data and instructions for performing actions on that data. Properly designed, these modules encapsulate data to hide implementation details, are versatile enough to be extended through inheritance, and give the programmer options through polymorphism. *Encapsulation, inheritance, and polymorphism* are features of every object-oriented language, including Java.

In addition to being object-oriented, the Java language can be used to create platform-independent applications. *Platform-independent applications* can be run on any computer regardless of operating system or hardware configuration. These features of Java have allowed programmers to create programs for the masses—similar to the way the Gutenberg press revolutionized the printing process, making printed materials available to the masses.

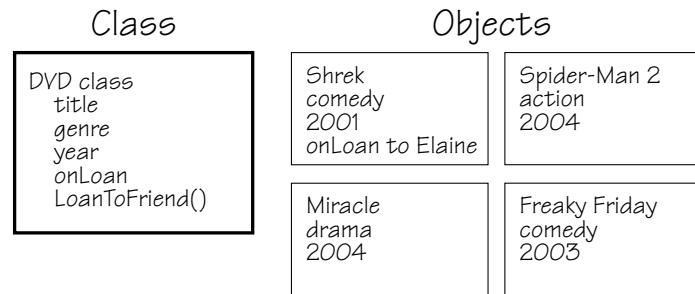
Objects, Classes, and Packages

Object-oriented program development involves selecting objects to perform the tasks outlined in a program specification. An *object* consists of related data and the instructions for performing actions on that data. The design for an object is called a class. A *class* defines the type of data and actions that will be associated with an object of that class, but not the actual data for an individual object. Classes are required to create objects. Many objects of the same class may be needed in an application.

Program Specification

A program specification is a definition or outline of what a program is expected to do. In industry, a program specification can serve as a contract between the programmer and the client.

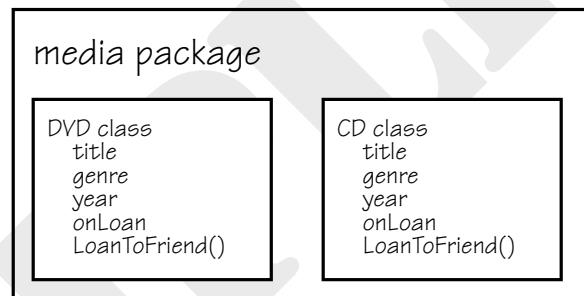
TIP *Reusability* is a term associated with object-oriented programming.



A class can be used to create many objects—each object will have the same type of data and possible actions, but each object maintains its own set of data.

package, library

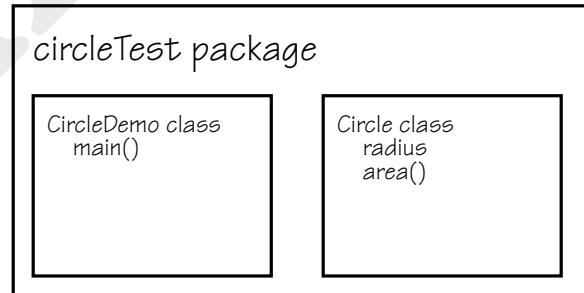
A *package*, sometimes called a *library*, is a group of related classes. For example, classes related to a particular task, such as input and output, can be grouped together in a package. A media package containing a DVD class and a CD class can be illustrated as:



A package contains related classes.

TIP Applications use, or import, packages to define objects.

An application is also contained in a package. It contains a controlling class and can contain other classes as well:



An application is contained in a package.

Packages are *importable*, which means an application can use existing classes from another package.

A Java Application

A *Java application* is a package with at least one class that contains a main() method. The following Greeting application is a simple, yet complete Java program:

```
/*
 * Greeting.java
 * A first Java application.
 * A Student
 * Course
 * Date
 */

package firstApplication;

/**
 * The Greeting class displays a greeting.
 */
public class Greeting {      //start class definition

    public static void main(String[] args) {
        System.out.println("Hello, world!");
    }
}                                //end class definition
```

TIP The static void in the main() method means that it is a method of the class and does not generate a value.

Greeting generates output similar to:

Hello, world!

statements

A program consists of a set of instructions called *statements*. A semi-colon is required to indicate the end of a statement. Related statements are enclosed by curly braces ({}) to begin and end the instructions. The statements in the Greeting application are:

controlling class
method

comments

- package firstApplication declares a package name. If a package name is not declared, then the application is given the package name Default by the compiler. Simple applications often do not have package statements.
- public class Greeting is a class declaration. The class is available to anyone (public) and is named Greeting. The Greeting class does not define any data or actions for objects. However, it contains the main() method making it the application's controlling class. The *controlling class* is a program's starting point.
- public static void main(String[] args) defines the main() method. A *method* is a named set of statements that perform a single, well-defined task. The main() method is placed in the controlling class. Its statements are automatically run when the program is executed. The statement in this main() method uses the println() method to display "Hello, world!" to the system output (the screen).

In addition to statements, programs contain *comments*, which provide information about the program to the reader of the code. Comments have no affect on the program, but they allow a reader of the program to quickly understand the purpose and logic behind segments of code. Because complex applications are often developed and maintained by more than one programmer, properly commented code allows for easier modifications and can decrease the number of mistakes.

Java programs can contain three types of comments:

- `/* */` are used to enclose single or multiline comments. These comments are appropriate at the beginning of a program to describe the application and where necessary to clarify a segment of code.
- `//` are used for adding a comment to the end of a statement or to create a single line comment. The `//` is also useful for debugging a program, which will be discussed in a later chapter.
- `/** */` are used for documentation. The javadoc tool copies these comments into a separate HTML document to create an instructional manual or external documentation. Documentation comments are appropriate for describing a class or method.

TIP The `main()` method does not typically have a comment block.

Multiline comments that describe a program, class, or method are sometimes referred to as a *comment block*. Tips throughout the text will provide additional pointers about commenting code.

Executing a Java Application

Java code typed by a programmer is called *source code*. For source code to *execute*, or *run*, it must be translated to code the computer understands in a process called *compiling*. Many Java compilers provide an environment for entering the source code as well as for compiling and running an application. Source code files have the extension `.java`, while compiled files have the extension `.class`.

Compiled Java source code is called *bytecode*. Executing a Java application means that its bytecode is interpreted with a *Java Virtual Machine* (Java VM). The *interpreter* runs each bytecode instruction as it is read. The Java VM can reside on any computer, regardless of operating system environment, making Java applications extremely portable, reliable, and platform-independent.

Although bytecode is versatile for porting applications to several different environments, programs compiled to machine code run faster. *Machine code* is comprised of just 1s and 0s and is different depending on the computer platform. A *just-in-time compiler* (JIT) converts bytecode to machine code before it is executed with the Java VM.

A program containing syntax errors will not compile. A *syntax error* occurs in a statement that violates the rules of Java. For example, all Java statements must end with a semicolon. A statement without a semicolon generates a syntax error when the program is compiled, preventing the compiler from generating bytecode for the application.

Virtual Machine

Virtual means not real. A virtual machine is therefore conceptual, not made of hardware and other physical components.

Review: Greeting

Create a Greeting application similar to the one shown in the “A Java Application” section. Refer to online materials at www.lpdatafiles.com for guidance with your Java compiler. Your instructor may also have specific information regarding your compiler. The goal of this review is to write the source code for a simple application and then compile and run the code.

Displaying Output

output stream

print() println()

TIP The System class is in the `java.lang` package.

An *output stream* sends data to an output device. To process data for the output stream, Java provides the `System` class with methods for displaying output. For displaying data to the standard output stream, which is typically the computer screen, use `System.out`. `out` contains `print()` and `println()` methods. The difference between these methods is how they control output. The `print()` method displays data and leaves the insertion point at the end of the output, while `println()` moves the insertion point to the next line after displaying output. The following application uses both methods:

```
/**  
 * Displays a welcome message.  
 */  
public class MulticulturalGreeting {  
  
    public static void main(String[] args) {  
        System.out.print("Hello");  
        System.out.print("Buenos Dias");  
        System.out.println("Bonjour");  
        System.out.println("How do you greet another?");  
    }  
}
```

argument

The `print()` and `println()` methods require arguments. An *argument* is data passed to a method for processing. In this case, the `print()` and `println()` arguments are strings. A *string* is a set of characters, which are enclosed by quotation marks.

string

`MulticulturalGreeting` produces output similar to:

**HelloBuenos DiasBonjour
How do you greet another?**

escape sequence

An *escape sequence* is a backslash (\) followed by a symbol that together represent a character. Escape sequences are used to display special characters. Common escape sequences include:

- \n newline
- \t tab (8 spaces)
- \\\ backslash
- \\" double quotation mark

The modified `MulticulturalGreeting` illustrates the use of escape sequences:

```
/**  
 * Displays a welcome message.  
 */  
public class MulticulturalGreeting {  
  
    public static void main(String[] args) {  
        System.out.print("Hello\t");  
        System.out.print("Buenos Dias\t");  
        System.out.println("Bonjour");  
        System.out.println("How do you greet another?");  
    }  
}
```

**Hello Buenos Dias Bonjour
How do you greet another?**

Review: AboutMe – part 1 of 2

Create an AboutMe application that displays your first name and last initial, your instructor's name, and your school name on three separate lines. Below the personal information, display a phrase that encourages your school team. For example, "Go Bears!" Be sure the phrase is displayed with quotation marks.

Numeric Output

The `NumberFormat` class, discussed in Chapter 4, can also be used to format numeric data.

TIP The `format()` method is new to Java 5 and requires JDK 5.

Formatting Output

The `format()` method can be used in place of the `print()` or `println()` methods to control the way output is displayed. The `format()` method arguments include a format string and an argument list. The format string contains specifiers that indicate how the corresponding strings in the argument list should be displayed. The following code demonstrates the `format()` method:

```
System.out.format("%-10s %8s %8s", "Team", "Wins", "Losses\n");
System.out.format("%-10s %8s %8s", "Jaguars", "10", "5\n");
System.out.format("%-10s %8s %8s", "Cheetahs", "14", "1\n");
System.out.format("%-10s %8s %8s", "Panthers", "8", "7\n");
System.out.format("%-10s %8s %8s", "Penguins", "4", "11\n");
```

When executed, the statements display:

Team	Wins	Losses
Jaguars	10	5
Cheetahs	14	1
Panthers	8	7
Penguins	4	11

A format string specifier takes the form:

`%[alignment][width]s`

- `%` indicates the start of a specifier
- `[alignment]` skip for right alignment.
Include a minus sign (-) for left alignment
- `[width]` the number of characters to use for output
- `s` indicates that the corresponding argument is a string

If `[width]` is greater than the number of characters in the corresponding string argument, then spaces pad the output. A string longer than `[width]` characters is displayed, but any strings to the right are moved over.

Text may also be included within the format string. For example, the statement:

```
System.out.format("The final game score: %-8s %8s", "10", "5");
```

displays:

The final game score: 10 5

Review: AboutMe – part 2 of 2

Modify the AboutMe application to include your class schedule, the days of the week that your class meets, and the start and end time of each class. Include code to properly align the data into three columns with the weekdays left aligned and the class start and end times right-aligned.

Code Conventions

Code conventions are a set of guidelines for writing an application. These guidelines provide details about commenting, rules for naming methods, classes, and packages, and statement formatting. Just as comments inform a reader about a segment of code, a program that follows specific code conventions is easier to read and understand.

A company or organization that employs programmers will typically adhere to specific code conventions. A programmer familiar with the code conventions will more quickly become familiar with code written by another programmer in the company. Code conventions can make modifying and maintaining code faster, easier, and less expensive. Because of these benefits, organizations often not only encourage the use of code conventions, but require it.

TIP Code conventions are important. About 80% of the lifetime cost of a piece of software goes to maintenance. Rarely is software maintained for its whole life by the original author.

The code conventions introduced in this chapter are:

- An introductory comment should begin a program. This comment should include information such as your name, class name, the date, and a brief statement about the program.
- Package names should begin with a lowercase letter and then an uppercase letter should begin each word within the name. Package names may not contain spaces.
- Class names should be nouns and begin with an uppercase letter and an uppercase letter should begin each word within the name. Class names may not contain spaces.
- A comment block should be included before each class and method. A comment block is not typically placed before the main() method.
- Comments should not reiterate what is clear from the code.
- Statements in a method should be indented.
- An open curly brace ({) should be placed on the same line as the class or method declaration, and the closing curly brace (}) should be on a separate line and aligned with the class or method declaration.

Algorithm Design

pseudocode flowcharts

Programs are created to solve problems. However, problems of any complexity require outlining, or designing, a solution before typing any source code. One method of design is called an algorithm. An *algorithm* is a set of steps that outline how to solve a problem.

Algorithms can be created in several ways. Often more than one approach is implemented. Steps written out in plain English is one approach. *Pseudocode* is a mix of English and program code, and is useful for refining a plain English algorithm. *Flowcharts* use symbols and text to give a visual representation of a solution.

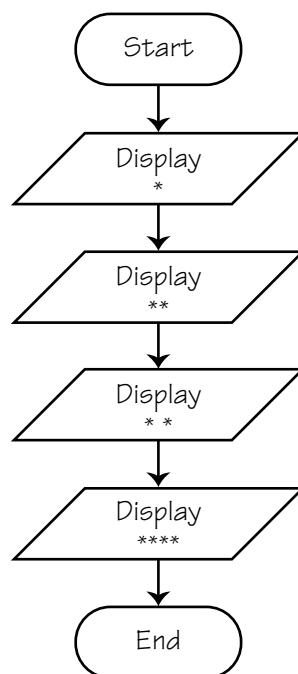
A description of the problem to be solved is used in developing an algorithm. For example, a program specification may state “The Triangle application displays a right triangle made up of the asterisk (*) symbol. The triangle should be 4 asterisks high by 4 asterisks wide.” Triangle appears to be a very simple application. From the description, we conclude that Triangle should display an image of a right triangle.

The next step after analyzing the problem is to produce the algorithm. In most cases, use more than one method to generate the algorithm to ensure that the solution to the problem is accurate. The following illustrates the Triangle program in both plain English steps and a flowchart:

The Triangle algorithm in plain English:

1. Print an asterisk to the screen.
2. Print two asterisks to the screen.
3. Print an asterisk followed by a space and an asterisk to the screen.
4. Print four asterisks to the screen.

The Triangle flowchart:



Each flowchart symbol has a different meaning. The  indicates start or end. The  shape indicates input/output. Other flowchart symbols will be introduced throughout the text as new concepts are covered.

Chapter Summary

This chapter introduced Java, which is an object-oriented programming language. OOP languages evolved out of the need to better develop complex programs. In addition to being object-oriented, Java is platform independent. Platform-independent applications can run on any computer, regardless of the operating system or hardware configuration.

Object-oriented languages use classes to define objects. A class defines the type of data and actions associated with an object, but not the actual data for an object. A package groups related classes.

A Java application is a package with at least one class. Statements in an application provide instructions. Methods are a named set of statements that perform a single, well-defined task. Comments in an application provide details about the code to the reader. Comments can be single or multiline and can also be extracted for documentation.

The code typed by a programmer is called source code. The source code is translated to bytecode with a compiler. Program execution occurs when the bytecode is interpreted with a Java Virtual Machine (Java VM). The Java VM can reside on any computer. A just-in-time (JIT) compiler converts bytecode to machine code before execution by the Java VM. Although less portable, machine code is faster. If a program contains errors, it will not compile. One type of error is the syntax error, which results when a statement violates the rules of Java.

Program output is through the output stream. The standard output stream is typically the computer screen and requires the `System.out` methods `print()` and `println()`. These methods require a string argument. Escape sequences are used to display special characters. Output can be formatted with the `format()` method.

Code conventions are a set of guidelines for writing an application. The code conventions introduced in this chapter are:

- An introductory comment should begin a program. This comment should include information such as your name, class name, the date, and a brief statement about the program.
- Package names should begin with a lowercase letter and then an uppercase letter should begin each word within the name. Package names may not contain spaces.
- Class names should be nouns and begin with an uppercase letter and then an uppercase letter should begin each word within the name. Class names may not contain spaces.
- A comment block should be included before each class and method. A comment block is not typically placed before the `main()` method.

- Comments should not reiterate what is clear from the code.
- Statements in a method should be indented.
- An open curly brace ({) should be placed on the same line as the class or method declaration, and the closing curly brace (}) should be on a separate line and aligned with the class or method declaration.

Programs are created to solve problems. However, problems of any complexity require outlining, or designing, a solution before typing any source code. One method of design is called an algorithm. An algorithm can be implemented through steps written in plain English, steps written in a mixture of code and English called pseudocode, or steps presented visually with a flowchart.

Vocabulary

Algorithm A set of steps that outline how to solve a problem.

Argument Data passed to a method for processing.

Bytecode Compiled Java source code.

Class The description of an object.

Code conventions A set of guidelines for writing an application.

Comment Text that provides information to the reader of program code.

Comment block Multiline comments that describe a program, class, or method.

Compiling The process where source code is converted to code the computer understands.

Controlling class The class in an application that contains the main() method.

Encapsulation An object-oriented language feature.

Escape Sequence A backslash followed by a symbol that together represent a character.

Execute To run a program.

Flowchart A visual representation of an algorithm.

Importable Package code that can be used by an application.

Inheritance An object-oriented language feature.

Interpreter Software that runs each bytecode instruction of a compiled Java program.

Java application A package with a controlling class and possibly other classes.

Java Virtual Machine (Java VM) The Java bytecode interpreter.

Just-in-time compiler (JIT) Software that converts bytecode to specific machine code.

Library *see* Package.

Machine code The most basic computer language, which is comprised of just 1s and 0s.

Method A named set of statements that perform a single, well-defined task. A method is always a member of a class.

Object A named entity that consists of related data and instructions for performing actions on that data.

Object-oriented programming (OOP) A systematic, modular approach to developing complex programs.

OOP *see* Object-oriented programming.

Output Stream Sends data to an output device, typically the computer screen.

Package A group of related classes. Also called a library.

Platform-independent application A program that can be run on any computer regardless of operating system or hardware configuration.

Polymorphism An object-oriented language feature.

Pseudocode An algorithm written in a mix of English and program code.

Run *see* Execute.

Source code The code typed by a programmer.

Statement An instruction in a program.

String A set of characters.

Syntax error A statement that violates the rules of Java.

`/* */` Used to enclose single or multiline comments.

`/** */` Used to enclose documentation comments.

`//` Used to begin a single line comment.

`{ }` Used to begin and end a set of related statements.

`;` Required at the end of each program statement.

`\\"` Escape sequence for displaying a backslash.

`\\"` Escape sequence for displaying a double quotation mark.

`\n` Escape sequence for displaying a newline.

`\t` Escape sequence for displaying a tab.

`class` Used to declare a class.

`format()` Method that displays more precisely formatted output to the screen.

`java.lang.System` The class that contains the `out` member.

`main()` The method in the controlling class that is automatically executed when a Java application is run.

`out` The `java.lang.System` member that represents the standard output stream.

`package` Statement used to declare a package.

`print()` Method that displays output to the screen.

`println()` Method that displays output to the screen and then moves the insertion point to the next line.

`public` An access modifier that declares a class or method as available to any code.

`static` A declaration used for class methods.

`void` Indicates a method will not return a value.

Critical Thinking

1. a) List three features of every object-oriented programming language.
b) Explain, in your own words, what you think the meaning is of each of the three features listed in part (a).
2. Draw a sketch that shows the relationship, and/or hierarchy, of object, class, and package for the package File, class FileReader, and the object fileInput.
3. Write an appropriate comment block for the beginning of a program to describe an application that is intended to calculate test averages.
4. Write an appropriate comment for describing a class that displays the average of a set of scores.
5. Write a statement that declares a package with the name gradeCalculator.
6. Write a statement that declares a class named AverageScore that is available to any code.
7. Explain the difference between source code and bytecode.
8. Describe machine code.
9. Explain the difference between a Java compiler and the Java VM.
10. What is the advantage of compiling Java source code using a JIT?
11. The following application has seven syntax errors. What are they?

```
//  
 * Test.java  
 * What's wrong application.  
 * Student Name  
 */  
  
package testMyKnowledge;  
  
/**  
 * The Test class should display a string,  
 */  
public class Test {  
  
    private static int main(string[] args) {  
        System.out.println("Testing...")  
    }  
}
```

12. Explain the difference between the print() and println() methods.
13. Explain the advantages of using the format() method in place of the print() and println() methods.
14. There are five places in which the application below does not follow the code conventions outlined in this chapter. Where are they?

```
/*  
 * getGreeting.java  
 * What's wrong application.  
 * Student Name  
 */  
  
package notSoGood;  
  
/**  
 * Good Morning is displayed.  
 */  
public class getGreeting {  
  
    public static void main(String[] args) {  
        //Output Good Morning to the screen  
        System.out.println("Good Morning");  
    } }
```

15. Explain the similarities and differences between pseudocode and a flowchart.

True/False

16. Determine if each of the following are true or false. If false, explain why.
 - a) Java applications can run only on the Windows platform.
 - b) Statements must end with a semicolon.
 - c) Comments have no effect on program execution.
 - d) The main() method is placed in the controlling class.
 - e) Related statements are enclosed with brackets ([]).
 - f) A file containing only source code can be executed on a computer.
 - g) Compiled source code is called machine code.
 - h) A program containing syntax errors will compile.
 - i) An algorithm is a set of steps that outline how to solve a problem.
 - j) Pseudocode cannot be used to implement an algorithm.

Exercises

Exercise 1

BingoCard

Create a BingoCard application that displays a traditional bingo card with five columns of five unique numbers. The column labels are B, I, N, G, and O. Column B contains numbers ranging from 1 through 15, column I has numbers ranging from 16 through 30, column N has four numbers ranging from 31 through 45 and a Free Space in the middle of the column, column G has numbers ranging from 46 through 60, and column O has numbers ranging from 61 through 75. The application output should look similar to:

B	I	N	G	O
2	20	42	60	64
14	25	32	55	70
5	18	FREE	53	67
12	16	31	46	75
10	22	39	59	71

Exercise 2

BingoRules

Create a BingoRules application that displays the rules for playing bingo. Place each rule on a separate line and place a blank line between rules. The application output should look similar to:

Bingo Card

1. The caller randomly pulls a numbered bingo ball.
2. The number is placed on the bingo board and called out.
3. Players look for the called number on their bingo card.
4. If the number is located, it is marked off.
5. Steps 1 to 4 are repeated until a player matches the BINGO pattern.
6. The winning player yells BINGO.

Exercise 3

Rectangle

Create a Rectangle application that displays a rectangle of asterisks (*). The rectangle should be 15 asterisks wide and 7 asterisks high. The application output should look similar to:

```
*****  
*   *  
*   *  
*   *  
*   *  
*   *  
*****
```

Exercise 4

RockPaperScissorsRules

Create a RockPaperScissorsRules application that displays the rules for playing Rock Paper Scissors. Place each rule on a separate line and place a blank line between rules. The application output should look similar to:

Rock Paper Scissors Rules

Players decide on different hand signals to represent rock, paper, and scissors.

Players make a throw at the same time.

The hand signals thrown by the players are then compared to the rules of the game to determine the winner:

Rock dulls Scissors (Rock wins).

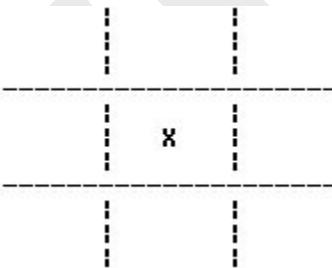
Scissors cuts Paper (Scissors wins).

Paper covers Rock (Paper wins).

Exercise 5

TicTacToeBoard

Create a TicTacToeBoard application that displays a tic-tac-toe board with an X in the center. The application output should look similar to:



Exercise 6

TicTacToeRules

Create a TicTacToeRules application that displays the rules for playing tic-tac-toe. Place each rule on a separate line and place a blank line between rules. The application output should look similar to:

Tic Tac Toe Rules

Tic Tac Toe is a game for 2 players.

1. A grid of 9 squares is drawn.

2. The first player draws an X in an empty square.

3. The second player draws an O in an empty square.

4. Steps 2 and 3 are repeated until a Tic Tac Pattern is created:

Patterns can be diagonal, horizontal, or vertical.

5. A winning pattern is completed by drawing a line through the pattern.

Exercise 7

Smile

Create a Smile application that displays a smiling face made of keyboard characters. The application output should look similar to:



Exercise 8

JavaTerminology

Create a JavaTerminology application that displays at least five words from the vocabulary list in this chapter and the corresponding definition. Place each word on a separate line followed by the definition. Place a blank line between entries. The application output should look similar to:

Java Terminology

Method:

A named set of statements that perform a single, well-defined task.

Statement:

An instruction in a program.

Exercise 9

FlowchartSymbols

Create a FlowchartSymbols application that illustrates the two flowchart symbols that were introduced in this chapter. The application output should look similar to:

Flowchart Symbols

Start or End Symbol:



Input/Output Symbol:



Exercise 10

CompilerDocumentation

Create a CompilerDocumentation application that creates compiler-specific documentation for the compiler you will be using in your class.

- a) Add the compiler name to the right of “Compiler” and then explain how to create a new project, enter source code, compile, and run a Java application using a format similar to:

Compiler:

Steps to create a new project:

Compile a project:

Run a project:

- b) Explore the compiler’s help features. Add documentation that explains how to use the compiler’s Help features.

Exercise 11

BinaryNumbers

As discussed in Chapter 1, computers are digital and they recognize two states: on and off. Therefore, the binary number system (base 2), which uses only two digits (0 and 1), was adopted for use in computers. Our most familiar number system is the decimal, or base 10, system. It uses ten digits: 0 through 9.

- a) Create a BinaryNumbers application that illustrates the binary numbers 1 through 20 and their decimal equivalents. Refer to chapter 1 for the conversion formula or if you have the Windows operating system, use the Microsoft Calculator in the Start → All Programs → Accessories menu to convert the numbers. In the Microsoft Calculator, select View → Scientific and then enter the number and select Bin to convert the decimal (Dec) number:



The application output should look similar to:

Decimal	Binary
1	1
2	10
3	11
4	100
.	.
.	.
20	10100

- b) The hexadecimal, or base 16, system is based on 16 digits: 0 through 9, and the letters A through F representing 10 through 15 respectively. Modify the BinaryNumbers application to include a Hexadecimal column that contains the corresponding hexadecimal numbers.

Exercise 12

ProgrammingLanguages

- a) Create a ProgrammingLanguages application that displays information about object-oriented programming languages. The application output should look similar to:

Object-Oriented Programming Languages
Java is an object-oriented programming language.
Other object-oriented languages include:

C++
Smalltalk

- b) Use books and the Internet to research other object-oriented programming languages and add three additional object-oriented programming languages to the list.

Chapter 4

Variables and Constants

Variables and constants are two important concepts explained in this chapter. Using primitive and abstract data types to declare variables is covered. User input, numeric expressions, and assignment operators are also discussed.

Declaring Variables

A *variable* is a name for a value stored in memory. Variables are used in programs so that values can be represented with meaningful names. For example, when a variable named `length` is used in a program, it is clear that its value is a distance. Variables should be used to represent values because they make code easier to read, understand, and modify.

declaration

A variable must be declared before it is used. A *declaration* takes the form:

```
<type> <name>
```

data type

The declaration includes two parts. The first is the *data type*, which determines the type of data the variable will store. The second part of a declaration is the variable name, called the *identifier*. For example, in the declaration

```
int length;
```

`int` is the data type and `length` is the identifier. An `int` stores an integer value, which is a positive or negative whole number. When an integer variable is declared it stores the value 0.

An identifier must begin with a letter and contain only letters, numbers, and some special characters. Typically variable identifiers begin with a lowercase letter. Any word after the first in a variable identifier should begin with an uppercase letter. For example, `rectangleLength`. This code convention allows variables to be easily recognized.

Multiple variables with the same data type can be declared in a single statement, similar to:

```
int length, width;
```

Grouping variables together in a single statement is good programming style when the variables represent related items. Declarations should not be grouped together in the same statement just because the variables are all the same type.

Using Variables

Applications typically contain many variables, as in RectangleArea:

```
/**  
 * Calculates and displays the area of a rectangle  
 */  
public class RectangleArea {  
  
    public static void main(String[] args) {  
        int length = 10;      //longer side of rectangle  
        int width = 2;        //shorter side of rectangle  
        int area;            //calculated area of rectangle  
  
        area = length * width;  
        System.out.println("Area of rectangle: " + area);  
    }  
}
```

RectangleArea produces output similar to:

Area of rectangle: 20

Variable declarations should be grouped at the beginning of a method. A blank line after the declarations makes it easy to determine where the declarations end.

assignment

equal sign

literal

initialize

concatenation

The value of a variable is changed through assignment. An *assignment statement* is formed with the variable name on the left side of an equal sign and the value it is to receive on the right side of the equal sign. The *equal sign* (=) is an operator that indicates that the variable on the left is to receive the value on the right. The value on the right can be a *literal*, which is any actual value. It could also be another variable or an expression. For example, `area` was assigned the value of the length multiplied by the width (`length * width`). Note that the * symbol indicates multiplication.

An assignment statement can be part of a variable declaration. In addition to being declared, the variable is *initialized*. For example, in RectangleArea, variables `length` and `width` were assigned values when declared.

A `System.out.println()` statement can be used to output the value of a variable. Variable identifiers are not enclosed by quotation marks. To append, or *concatenate*, the value of a variable to a string, the + operator is used. The + operator converts the value of the variable to a string and then concatenates the strings before output.

It is important to realize that a variable can store only one value at any one time. For example, after the following statements execute

```
int x;      x  
x = 5;        
x = 10;     x  
              
            5  
            x  
              
            10
```

the value of `x` is 10 because this was the last value assigned to `x`.

Review: RectanglePerimeter

Create a RectanglePerimeter application that calculates and displays the perimeter of a rectangle with width 4 and length 13. The perimeter of a rectangle is calculated as $2w + 2l$. Use variables as appropriate.

Primitive Data Types

The `int` data type is called a primitive data type. A variable that is defined with a *primitive data type* stores a single piece of data. Java supports several primitive data types, including:

Type	Bytes	Data Range
<code>int</code>	4	a positive or negative integer from -2,147,483,648 to 2,147,483,647
<code>double</code>	8	a positive or negative number that may contain a decimal portion in the range -1.7E+308 to 1.7E+308
<code>char</code>	2	a single character
<code>boolean</code>		true or false

An `int` variable uses 4 bytes of memory to store its value and is used for representing whole numbers.

Values that are represented by the `double` data type are sometimes referred to as *floating point*, meaning that the values contain numbers after the decimal point. Because of the many digits that are possible in a `double`, a variable of this type uses 8 bytes of memory.

A `char` variable requires 2 bytes of memory because Java uses the 16-bit Unicode character encoding. Assignment to a `char` variable requires enclosing a single character in single quotation marks, as in '`a`'.

Variables that are type `boolean` can have only one of two values—`true` or `false`. Boolean variables are particularly useful for representing yes/no or on/off values.

When choosing a data type, it is important to choose the most appropriate type for the quantity being represented. If a value could possibly have a decimal portion, then `double` is the best choice. If a variable will represent only whole numbers, then `int` is the best choice even though `double` will work. Using the most appropriate data types for variables has two benefits. First, both the compiler and the reader will understand the possible values for a variable. Second, the compiler allocates the appropriate memory for the variable.

choosing data types

TIP Primitive data types are also called built-in data types.

Review: Distance – part 1 of 2

Create a Distance application that calculates and displays the total distance of a race with three segments. The first segment is 12.2 km, the second is 10.6 km, and the third is 5.8 km. Use variables of the appropriate type.

Abstract Data Types

In addition to primitive data types, a variable can be declared using an abstract data type. One kind of *abstract data type* is the class. Many classes are provided in Java, and many more classes will be created throughout this text. Each class defines not just a single piece of data like a primitive data type, but a set of data along with methods for performing actions on that data.

object

A variable declared with a class is called an *object*. The variable itself actually stores a reference to the area in memory where the object's data and methods are stored:



instantiation

Creating a new object is called *instantiation*. In addition to declaring a variable to refer to the object, the object must be created and initialized in a statement that takes the form:

```
<class> <variable name> = new <class>(<arguments>);
```

The `new` operator allocates memory for the object and returns a reference to the object. `<arguments>` are used to initialize the data for the object.

The code below creates a new object using a class named `Circle`:

```
Circle spot = new Circle(4); //spot with radius 4
```

In this statement, the variable `spot` refers to a `Circle` object that has been initialized with a radius of 4.

To access a member of a class, such as a method, use the object name followed by a dot (.) and then the member name. For example, the code below executes method members `getRadius()` and `area()`:

```
Circle spot = new Circle(4);
System.out.println("Radius of spot is " + spot.getRadius());
System.out.println("Area of spot is " + spot.area());
```

These statements produce output similar to:

```
Radius of spot is 4.0
Area of spot is 50.24
```

The `Circle` class will be developed later in this text.

Package Documentation

Package documentation typically summarizes the package classes and the data and methods available in those classes. Code examples that use the classes may also be included in the documentation. Documentation for Java packages are available online at www.sun.com.

Java Packages

Java includes numerous packages as part of the Java Runtime Environment (JRE). These packages contain general use classes, utility classes, or special purpose classes. The most fundamental package is `java.lang` with classes that define the language itself. Other packages such as `java.util` have classes for reading input and generating random numbers. These packages will be explained and used throughout this text.

TIP Companies sometimes use their reversed Internet domain in package names. For example, com.mycompany.util names a package with utility classes.

import

java.lang

TIP The Scanner class is new to Java 5.

input stream

Scanner

exception

Packages follow a certain naming convention. Java packages start with `java` followed by a dot (.) and then the package name. Companies and other organizations will often name a package with the organization name followed by a dot and then the package name.

The `import` statement is used to make the members of a package accessible to an application. To make a single class from a package accessible, a statement similar to the following is used:

```
import java.util.Scanner;
```

The class name starts with an uppercase letter, following the appropriate naming convention for class names. If several classes in a package are to be accessible, then a statement that imports the entire package may be used:

```
import java.util.*;
```

The asterisk (*) indicates that all members of the `util` package are to be accessible. `import` statements must appear after a package statement and before any class definitions. Java applications automatically import the entire `java.lang` package.

Obtaining a Value from the User

An application is more flexible when values can be read from an input stream. An *input stream* is the sequence of characters received from an input device, such as a keyboard. For example, as a user types data, the data goes into the input stream. To process data in the input stream, Java includes the `Scanner` class with methods for reading integers, floating point numbers, and strings.

A program that obtains a value from the user must instantiate a `Scanner` object that is initialized with an input stream. For data typed from a keyboard, initialize the object with `System.in` because it represents the standard input stream.

`Scanner` class methods include:

Class `Scanner` (`java.util.Scanner`)

Methods

<code>next()</code>	returns a string from the input stream.
<code>nextLine()</code>	returns the string up to the end of line character from the input stream.
<code>nextInt()</code>	returns the <code>int</code> read from the input stream.
<code>nextDouble()</code>	returns the <code>double</code> read from the input stream.
<code>nextBoolean()</code>	returns the <code>boolean</code> read from the input stream.
<code>close()</code>	closes the input stream.

The `next()` method is used for reading a string that does not contain spaces. For example, “apple”. Attempting to read the string “apple pie” generates a run-time exception called `InputMismatchException`. An *exception* is an error affecting program execution. Exceptions are discussed later in this chapter.

reading numbers and strings

When reading in a combination of numeric and string data, the next() method should be used for reading string data after reading numeric data. Using the nextLine() method is ineffective. It reads the end-of-line character left by the numeric data entry, essentially reading an empty string. If a string with multiple words is expected from the user, the nextLine() can be used to read in the end-of-line character and then another nextLine() used to read the string.

The RectangleArea2 class below instantiates a Scanner object and reads values typed by the user:

```
import java.util.Scanner;

/**
 * Calculates and displays the area of a rectangle
 * based on the width and length entered by the user.
 */
public class RectangleArea2 {

    public static void main(String[] args) {
        int length;      //longer side of rectangle
        int width;       //shorter side of rectangle
        int area;        //calculated area of rectangle
        Scanner input = new Scanner(System.in);

        System.out.print("Enter the length: ");
        length = input.nextInt();
        System.out.print("Enter the width: ");
        width = input.nextInt();
        input.close();

        area = length * width;
        System.out.println("Area of rectangle: " + area);
    }
}
```

Note that the `import` statement appears above the class. RectangleArea2 produces output similar to the following when values 6 and 2 are typed by the user:

```
Enter the length: 6
Enter the width: 2
Area of rectangle: 12
```

prompt

In the RectangleArea2 code, a Scanner object is declared, instantiated, and initialized in the statement `Scanner input = new Scanner(System.in)`. The calls to the `nextInt()` method are used to obtain the values typed by the user. When a call to `nextInt()` occurs, the application waits until the user types a value and presses enter before the next statement is executed. The application also includes *prompts* that tell the user what kind of input is expected. For example, `System.out.print("Enter the length: ")` prompts the user for a length value. When a Scanner object is no longer needed, it should be closed with the `close()` method.

Review: Distance – part 2 of 2

Modify the Distance application to first prompt the user for the distance of each race segment and then prompt the user for the runner's name. The application should then display the runner's name and total distance to run.

Numeric Expressions

Object Operators

Objects typically cannot be manipulated with the built-in arithmetic operators. A class usually defines methods that are used to perform operations on objects.

Integer division

Java includes built-in arithmetic operators for addition (+), subtraction (-), multiplication (*), division (/), and modulus division (%). These operators are for use with primitive data and can be used to form numeric expressions. A *numeric expression* contains at least one operand, which is a value or primitive variable, and may contain operators. For example, the numeric expression $6 + 5$ contains two operands and one operator. Numeric expressions can be used in assignment statements, as in the statement `area = length * width`.

The / division operator performs differently depending on the data type of the operands. When both operands are type `int`, the / operator performs integer division. *Integer division* truncates the decimal portion of the quotient to result in an integer:

$$\begin{array}{r} 20/7 \\ \underline{(2)} \text{ r } 6 \\ 7)20 \\ \underline{14} \\ 6 \end{array}$$

Real division returns the entire quotient, including the decimal portion, and is performed when one or both operators are type `double`.

modulus division

Modulus division returns the remainder resulting from division. The % operator truncates the operands, if necessary, to return an integer:

$$\begin{array}{r} 20 \% 7 \\ \underline{2} \text{ (r } 6\text{)} \\ 7)20 \\ \underline{14} \\ 6 \end{array}$$

Modulus division is useful for retrieving digits of a number.

The statements below demonstrate the division operators:

```
int num1 = 5;
int num2 = 3;
int result;
double doubleNum1 = 5;
double doubleNum2 = 3;
double doubleResult;

result = num1 / num2;
System.out.println("num1 / num2: " + result);

doubleResult = doubleNum1 / doubleNum2;
System.out.println("doubleNum1 / doubleNum2: "
+ doubleResult);

doubleResult = num1 / doubleNum2;
System.out.println("num1 / doubleNum2: " + doubleResult);

result = num1 % num2;
System.out.println("num1 % num2: " + result);

doubleResult = doubleNum1 % doubleNum2;
System.out.println("doubleNum1 % doubleNum2: "
+ double Result);
```

Executing the statements on the previous page produces the output:

```
num1 / num2: 1
doubleNum1 / doubleNum2: 1.6666666666666667
num1 / doubleNum2: 1.6666666666666667
num1 % num2: 2
doubleNum1 % doubleNum2: 2
```

operator precedence

Java evaluates an expression using a specific order of operations based on operator precedence. *Operator precedence* is the level assigned to an operator. Multiplication and division (including modulus division) have the highest precedence, followed by addition and subtraction. Two operators of the same precedence are evaluated in order from left to right.

order of operations

The order of operations can be changed by including parentheses in a numeric expression. The operations within parentheses are evaluated first. For example, the expression $6 + 4 * 2 - 1$ evaluates to 13, and the expression $(6 + 4) * (2 - 1)$ evaluates to 10. It is also considered good programming style to include parentheses when there is any possibility of ambiguity or question about the expression.

Review: Digits

Create a Digits application that prompts the user for a two-digit number and then displays the ones-place and tens-place digits.

Type Casting

Type casting converts a number of one type to a number of a different, but compatible type. For example, a `double` can be cast as an `int`, as in the statements:

```
int i = 2;
double d = 3.7;
int x;
x = i * (int)d //d is explicitly cast; x is assigned 2x3
```

Type casting is necessary in this case because one of the operands in the expression has less precision than the variable that will store the result. Explicit casting also makes it clear that the programmer intended for the calculation result to be an `int`.

truncate

TIP Truncation is always toward 0.

Casting a `double` to an `int` *truncates*, or removes, the decimal portion of the number, as in the statements above. When decreasing the precision of a number, it is better to round the number. A number with a decimal portion greater than or equal to 0.5 should be rounded up to the next integer, and a number with a decimal portion less than 0.5 should be rounded down. For example, rounding 3.7 results in 4.

rounding

Rounding can be simulated when casting a `double` to an `int` by adding 0.5 to the number before casting, as in the statement:

```
x = i * (int)(d + 0.5)      //x is assigned 2x4
```

If casting a negative number, then 0.5 should be subtracted from the number before casting.

real division

Casting is useful when real division with integers is preferred. The following statements demonstrate the difference between integer division and real division with integers:

```
int i = 5;  
int j = 2;  
double result;  
  
result = i / j;          //integer division; result=2  
result = (double)i / (double)j; //real division; result=2.5
```

Java will implicitly type cast operands in a mixed expression to match the precision of the variable storing the result, as in the statements:

```
int i = 2;  
double d = 3.7;  
double y;  
  
y = i * d      //i is implicitly cast; y is assigned 2.0x3.7
```

Although explicit type casting is not necessary in this case, it is better programming style to include casts. Casting makes a programmer's intentions clear and may make bugs easier to find. Therefore, the statements above should be written as:

```
int i = 2;  
double d = 3.7;  
double y;  
  
y = (double)i * d      //better code; y is assigned 2.0x3.7
```

Review: GradeAvg – part 1 of 2

Create a GradeAvg application that prompts the user for five grades and then displays the average of the grades. Assume the grades are integer values (for example, 89, 97, and so on). Real division should be performed when calculating the average.

Review: TempConverter

Create a TempConverter application that converts a Fahrenheit temperature to the corresponding Celsius temperature. The formula for converting Fahrenheit to Celsius is $C = \frac{5}{9}(F - 32)$. The application should prompt the user for the Fahrenheit temperature. Be sure to carefully form the expression. Parentheses will be needed to specify the order of operations.

Formatting Numeric Output

java.text

The DecimalFormat Class

The DecimalFormat class offers additional options for formatting numbers to a specified decimal place. Refer to Java online documentation for more information.

The format() Method

The format() method, discussed in Chapter 3, can also be used to format numeric values. A specifier can take the form:

%[alignment][width][.decimal]f

where [.decimal] indicates the number of decimal places and f indicates a floating point number. For an integer, the specifier takes the form:

%[alignment][width]d

The NumberFormat class, which is part of the java.text package, is used to create objects that format numbers. NumberFormat objects return a string that contains a formatted number. The formatting of the number depends on which NumberFormat object is used. The NumberFormatExample application creates four different NumberFormat objects:

```
import java.text.NumberFormat;

public class NumberFormatExample {

    public static void main(String[] args) {
        double dollars = 21.5;
        int num = 1234;
        double numWithDecimal = 2.0 / 3.0;
        double sale = .15;
        NumberFormat money = NumberFormat.getCurrencyInstance();
        NumberFormat number = NumberFormat.getIntegerInstance();
        NumberFormat decimal = NumberFormat.getNumberInstance();
        NumberFormat percent = NumberFormat.getPercentInstance();

        System.out.println(money.format(dollars));
        System.out.println(number.format(num));
        System.out.println(decimal.format(numWithDecimal));
        System.out.println(percent.format(sale));
    }
}
```

When executed, the application produces the following output:

```
$21.50
1,234
0.667
15%
```

Assignment Operators

In an assignment statement, the expression on the right side of the equal sign (=) is evaluated first and then that value is given to the variable on the left. Because the expression on the right is evaluated before an assignment is made, it is possible to use the current value of the variable in the expression itself. For example:

```
numPlayers = 12;           //numPlayers is assigned 12
numPlayers = numPlayers + 2; //numPlayers is now 14
```

Changing the value of a variable based on its current value is often done in programming. Therefore, in addition to the = assignment operator, Java recognizes the +=, -=, *=, /=, and %= assignment operators. These operators perform an operation before making an assignment. For example, the previous assignment statement can be rewritten as:

```
numPlayers += 2;           //numPlayers is now 14
```

The -=, *=, /=, and %= operators work similarly, as in the statements:

```
numPlayers -= 3;           //same as: numPlayers = numPlayers - 3
numCopies *= 5;            //same as: numCopies = numCopies * 5
total /= 2;                //same as: total = total / 2
remainder %= 6;             //same as: remainder = remainder % 6
```

Review: GradeAvg – part 2 of 2

Modify the GradeAvg application to use the `+=` operator to sum the grades as they are entered by the user. Format the average grade to display as a percentage.

Using Named Constants

When should a named constant be used?

Named constants should be used wherever they can add clarity to code. However, there are some values that should not be replaced with named constants. For example, in an expression that calculates the area of a triangle ($\frac{1}{2}bh$), the value 0.5 is best used instead of a named constant because the value does not have an obvious name.

A *constant* is a name for a memory location that stores a value that cannot be changed from its initial assignment. Constants, like variables, are used in programs so that values can be represented with meaningful names. A constant declaration is a variable declared `final` and takes the form:

```
final <type> <identifier>
```

The declaration begins with `final`, which indicates that the value will not change, followed by the type of data the constant will store and the constant identifier. For example, the following declaration represents π :

```
final double PI = 3.14;
```

`double` declares a numeric value possibly containing a decimal portion. Constant identifiers are typically all uppercase, and may include underscore (_) characters to separate words. For example, `MAX_PRICE`.

The following class uses a constant in the `main()` method:

```
/**  
 * Calculates and displays the area of a circle  
 */  
public class CircleArea {  
  
    public static void main(String[] args) {  
        final double PI = 3.14;  
        double radius = 5;      //radius of circle  
        double area;  
  
        area = PI * radius * radius;  
        System.out.println("Area of circle: " + area);  
    }  
}
```

`CircleArea` produces output similar to:

Area of circle: 78.5

A constant can be assigned a value only once. Trying to change the value of a constant after the initial assignment generates an error. Constant declarations should be grouped at the beginning of a method before any variable declarations.

Identifiers and Keywords

case sensitivity

Identifiers in Java must begin with a letter and may contain letters, numbers, and some special symbols. Periods and spaces are not allowed. Identifiers are also *case sensitive*, which means that an uppercase letter is different from the same letter in lowercase. For example, identifiers `Count` and `count` are viewed by Java as two different identifiers.

The Java language contains *keywords*, which have special meaning to the Java compiler and therefore cannot be used for a variable or constant identifier. The Java keywords are:

abstract	double	int	strictfp
boolean	else	interface	super
break	extends	long	switch
byte	final	native	synchronized
case	finally	new	this
catch	float	package	throw
char	for	private	throws
class	goto	protected	transient
const	if	public	try
continue	implements	return	void
default	import	short	volatile
do	instanceof	static	while

Although `not`, `true`, `false`, and `null` are reserved and not for use as identifiers.

Review: CircleCircumference – part 1 of 2

Create a `CircleCircumference` application that calculates and displays the circumference of a circle. The application should prompt the user for the value of the radius. The circumference of a circle is calculated as $2\pi r$. Use variables and constants as appropriate.

Programming Errors

There are many types of errors that can occur in a program. Some errors are found by the compiler. Others occur at run time. A program that has been carefully designed will have fewer errors. Code reuse can also lead to fewer errors because packages that have been carefully tested and properly documented produce cleaner and more robust code.

syntax error

Errors that violate the rules of Java are called *syntax errors*. For example, forgetting a semicolon at the end of a statement generates a syntax error. Syntax errors are found by the compiler. An application with syntax errors will not run because it will not compile.

logic error, semantic error

A *logic error*, also called a *semantic error*, is more difficult to detect. Logic errors occur in statements that are syntactically correct, but produce undesired or unexpected results, as in the following example:

```
int length;  
int area;  
  
length = 3.2;           //3 is actually assigned  
area = length * length; //expected value is 10.24
```

The statements assign the value 9 to `area` rather than the expected 10.24. Although, it is possible that the programmer intended for the value to be truncated, it is more likely that variables `length` and `area` were supposed to be declared as `double`.

Logic errors must be found by the programmer through testing and by carefully examining the source code. Accurate and careful commenting, proper indentation, and descriptive identifiers can help in finding and preventing logic errors.

run-time error, exception

Errors that are not detected by the compiler may generate a *run-time error*. A run-time error, also called an *exception*, halts program execution at the statement that cannot be executed. For example, although the statements below are syntactically correct, they will generate a run-time error because division by 0 is undefined:

```
int totalScores = 40;  
int totalTests = 0;  
double avgScore;  
avgScores = totalScores / totalTests;
```

ArithmeticException

This code generates an `ArithmeticException` exception.

InputMismatchException

Exceptions can also be generated when user input is not as expected. For example, the application run below generates an `InputMismatchException` exception because the user typed a string when a numeric was expected:

```
Enter the length: a  
Exception in thread "main" java.util.InputMismatchException  
at java.util.Scanner.throwFor<Scanner.java:819>  
at java.util.Scanner.next<Scanner.java:1431>  
at java.util.Scanner.nextInt<Scanner.java:2040>  
at java.util.Scanner.nextInt<Scanner.java:2000>  
at RectangleArea2.main<RectangleArea2.java:12>
```

The program only had code to handle numeric user input. When a letter, rather than a number was typed, an exception was “thrown.” Writing code to handle exceptions is discussed in Chapter 12.

Chapter 4 Case Study

This and all subsequent chapters end with a case study. Case studies are used to learn problem-solving techniques. Each case study will include a description, program specification, code design, program implementation, and a discussion about testing and debugging.

In this case study, a Birthday game will be created. The BirthdayGame guesses a player's birthday by having the player perform mathematics with the month and day of their birthday. The number computed by the player is then entered and the program displays the month and day of the player's birthday.

BirthdayGame Specification

BirthdayGame is played with one player. The player is given directions for computing a number that uses the player's birth month and birth day in the calculations:

1. Determine your birth month (January=1, February=2, and so on).
2. Multiply that number by 5.
3. Add 6 to that number.
4. Multiply the number by 4.
5. Add 9 to the number.
6. Multiply that number by 5.
7. Add your birth day to the number (10 if born on the 10th and so on).

BirthdayGame prompts the player for the calculated number and then displays the player's birthday. To determine the player's birthday, 165 is subtracted from the number entered by the player. This number is then divided by 100. The decimal portion of the quotient represents the birth month. The remainder of the division is the birth day.

The BirthdayGame interface should consist of steps that tell the user how to calculate the number that needs to be entered. The player should then be prompted for their number. Finally, the application displays the player's birthday.

A sketch of a program run:

Using paper and pencil, perform the following calculations:

1. Determine your birth month (January=1, February=2 and so on).
2. Multiply that number by 5.
3. Add 6 to that number.
4. Multiply the number by 4.
5. Add 9 to the number.
6. Multiply that number by 5.
7. Add your birth day to the number (10 if the 10th and so on).

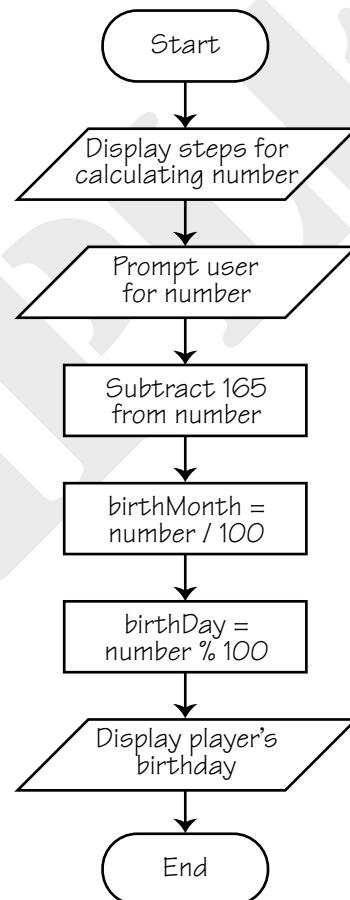
Enter your number: 393

Your birthday is 2/28

An algorithm in plain English for BirthdayGame:

1. Display the directions for the player to calculate the number.
2. Prompt the player for the calculated number.
3. Subtract 165 from the number.
4. Use integer division to divide the number by 100. Store the quotient as the birth month.
5. Use modulus division to divide the number by 100. Store the remainder as the birth day.
6. Display a message containing the player's birthday.

The BirthdayGame flowchart:



TIP The flowchart object represents a process.

BirthdayGame Code Design

The code design describes how to accomplish the specification. Included in the code design are a description of the input, output, data generated, and additional flowcharts, algorithms, and pseudocode.

The input for BirthdayGame is a number calculated by the user. An integer variable to store the user's input will be needed.

The output for BirthdayGame is a message with the user's birthday.

Data generated by BirthdayGame is the birth month and the birth day. Integer variables to store the birth month and birth day will be needed.

Based on the algorithm and flowchart, the code design for the BirthdayGame application will include statements for input and output. Calculations will require both integer and modulus division. A pseudo-code algorithm for BirthdayGame follows:

```
Display directions (7 steps)
Prompt the user for the calculated number
playerNum -= 165
birthMonth = playerNum / 100
birthDay = playerNum % 100
Display player's birthday
```

BirthdayGame Implementation

Based on the code design, the BirthdayGame implementation follows:

```
/*
 * BirthdayGame.java
 */

import java.util.Scanner;

/**
 * Plays a birthday guessing game with one player.
 */
public class BirthdayGame {

    public static void main(String[] args) {
        int playerNum;
        int birthMonth, birthDay;
        Scanner input = new Scanner(System.in);

        /* Give the player directions for calculating the number */
        System.out.println("Using paper and pencil, perform the following
                           calculations:\n");
        System.out.println("1. Determine your birth month (January=1, February=2
                           and so on).");
        System.out.println("2. Multiply that number by 5.");
        System.out.println("3. Add 6 to that number.");
        System.out.println("4. Multiply the number by 4.");
        System.out.println("5. Add 9 to the number.");
        System.out.println("6. Multiply that number by 5.");
        System.out.println("7. Add your birth day to the number (10 if the 10th
                           and so on).\n");
    }
}
```

```

        System.out.print("Enter your number: ");
        playerNum = input.nextInt();
        input.close();

        /* Calculate birth day and month and display result. */
        playerNum -= 165;
        birthMonth = playerNum / 100;
        birthDay = playerNum % 100;

        System.out.println("Your birthday is " + birthMonth + "/" + birthDay);
    }
}

```

A run of BirthdayGame looks similar to:

Using paper and pencil, perform the following calculations:

1. Determine your birth month (January=1, February=2 and so on).
2. Multiply that number by 5.
3. Add 6 to that number.
4. Multiply the number by 4.
5. Add 9 to the number.
6. Multiply that number by 5.
7. Add the birth day to the number (10 if the 10th and so on).

```

Enter your number: 572
Your birthday is 4/7

```

BirthdayGame Testing and Debugging

This case study performs minimal calculations and the algorithm is simple and straight forward. Simply testing it with your birthday is one method of verifying results.

Chapter Summary

Variables and constants are used in programs so that values can be represented with meaningful names. Variables and constants should be used because they make code easier to read, understand, and modify.

Both variables and constants are created with a declaration statement. A variable declaration includes the data type and identifier. A constant declaration also includes the keyword `final`. Identifiers are case sensitive and cannot be the same as a Java keyword. The value of a variable can be changed throughout program execution with assignment statements. The value of a constant cannot be changed from its initial assignment.

A primitive data type stores a single piece of data and can include `int`, `double`, `char`, and `boolean`. Abstract data types include classes. Each class defines not just a single piece of data like a primitive data type, but a set of data along with methods for performing actions on that data. Variables declared with an abstract data type are called objects. An object declaration is called instantiation. An object is instantiated with the keyword `new`.

Data can be read from the user at run time by using the `Scanner` class. This class processes data from the input stream. Objects that read data from the keyboard are initialized with `System.in`. When obtaining data from the user, a prompt should be included so that the user knows what information is expected.

Java includes many packages. Package members are accessible with an `import` statement. The `Scanner` class is in the `java.util` package. The `NumberFormat` class is in the `java.text` class. The `NumberFormat` class is used for formatting numbers.

Java includes built-in operators that are used to form numeric expressions. Arithmetic operators include `+`, `-`, `*`, `/`, and `%`. The `/` operator performs integer division when both operands are type `int`, and real division when at least one operand is a `double`. Modulus division is performed with the `%` operator. An expression is evaluated according to operator precedence. The order of operations can be changed with parentheses. Assignment operators include `+=`, `-=`, `*=`, `/=`, and `%=`. Each of these operators perform an operation before making an assignment.

Type casting converts a number of one type to a number of a different type. Casting is useful when real division with integers is preferred. A `double` can be rounded by first adding 0.5 before casting to an `int`.

Programming errors occur for many reasons. A syntax error violates the rules of Java. A logic error is also called a semantic error and is more difficult to detect because statements are syntactically correct, but produce unexpected results. A run-time error is also called an exception. An exception halts program execution.

Code conventions introduced in this chapter are:

- Variable identifiers begin with a lowercase letter and any word after the first within the identifier should begin with an uppercase letter.
- Constant identifiers are all uppercase. Multiple words in an identifier can be separated with an underscore (`_`) character.
- Variable and constant declarations should be grouped at the beginning of a method.
- Each line of a program should contain only one statement.

Vocabulary

Abstract data type A class. A data type that can store data and methods.

ArithmetException exception An exception thrown when division by 0 occurs.

Assignment statement A statement that gives the variable or constant on the left of an assignment operator the value of the expression on the right side of the assignment operator.

Case sensitive An uppercase letter is different from the same letter in lowercase.

Class *see* Abstract data type.

Concatenate To join two or more strings to form one larger string.

Constant A name for a memory location that stores a value than cannot be changed from its initial assignment.

Data type The kind of information a variable stores.

Declaration A statement that creates a variable or constant.

Equal sign (=) An assignment operator that indicates the variable or constant on the left is to receive the value of the expression on the right.

Exception *see* Run-time error.

Floating point Values that are represented by the double data type. Values that contain numbers after the decimal point.

Identifier A name for a variable or constant. An identifier must begin with a letter and can include any number of letters, numbers, and some special characters.

Initialize To assign a variable a value in a declaration statement.

InputMismatchException exception An exception thrown when user input is not as expected.

Input stream The sequence of characters received from an input device.

Instantiation To create a new object.

Integer division Division that truncates the decimal portion.

Keyword A word that has special meaning to the Java compiler and therefore cannot be used as a variable or constant identifier.

Literal An actual value.

Logic error An error caused by a statement that is syntactically correct, but produces unexpected or undesired results. Also called a semantic error.

Modulus division Division that returns the remainder.

Numeric expression At least one operand and possibly one or more operators that evaluate to a single value.

Object A variable declared with a class.

Operator precedence The level assigned to an operator so that a specific order of operations is maintained.

Primitive data type A data type that can store only a single piece of data. Primitive data types are also called built-in data types.

Prompt A string that informs the user of the kind of data expected to be typed.

Run-time error An error affecting program execution. Also called an exception.

Semantic error *see* Logic error.

Syntax error An error caused by a statement that violates the rules of Java.

Truncate Removing the decimal portion of a number when casting a `double` to an `int`.

Type casting Converting a number from one type to a different type.

Variable A name for a memory location that stores a value.

- + Operator used for concatenating strings.
 - + The arithmetic addition operator.
 - The arithmetic subtraction operator.
 - * The arithmetic multiplication operator.
 - / The arithmetic division operator.
 - % The arithmetic modulus division operator.
 - () Used to change the order of operations in an expression. Also used for type casting.
 - = An assignment operator that gives the variable on the left the value on the right.
 - += An assignment operator that adds the value on the right to the variable on the left and then assigns that value to the variable on the left.
 - = An assignment operator that subtracts the value on the right from the variable on the left and then assigns that value to the variable on the left.
 - *= An assignment operator that multiplies the value on the right by the value of the variable on the left and then assigns that value to the variable on the left.
 - /= An assignment operator that divides the value of the variable on the left by the value on the right and then assigns that value to the variable on the left.
 - %= An assignment operator that divides the value of the variable on the left by the value on the right and then assigns the remainder of that division to the variable on the left.
- `boolean` A data type that represents true or false.
- `char` A data type that represents a single character.
- `double` A data type that represents positive or negative floating point numbers.
- `final` Keyword used to declare an identifier a constant.
- `import` Statement used to make a package or classes from a package accessible to an application.
- `in` The `java.lang.System` member that represents the standard input stream.
- `int` A data type that represents positive or negative integers.

`java.lang` The most fundamental Java package. It contains classes that define the Java language.

`java.text` A Java package with the `NumberFormat` class for formatting numbers.

`java.util` A Java package with the `Scanner` class for reading input.

`new` An operator that allocates memory for an object.

`NumberFormat` A `java.text` class with methods for formatting numbers.

`Scanner` A `java.util` class with methods for reading input from the user.

`System.in` The input stream for reading from the keyboard.

Critical Thinking

1. a) List four legal identifier names.
b) List four illegal identifier names and explain why each is illegal.
2. a) In two statements, declare a variable named `numBeads` and assign it the value 5.
b) In one statement, declare a variable named `numBeads` and assign it the value 5.
3. a) What is the final value of `yourNumber` after the last statement executes?

```
int myNumber = 5;
int yourNumber = 4;
myNumber = yourNumber * 2;
yourNumber = myNumber + 5;
```

b) What is the final value of `yourNumber` after the last statement executes?

```
int myNumber;
int yourNumber = 4;
myNumber = yourNumber + 7;
yourNumber = myNumber;
```
4. Determine the appropriate data type for each of the following values:
 - a) the number of basketballs in a department store.
 - b) the price of a basketball.
 - c) the number of players on a basketball team.
 - d) the average age of the players on a basketball team.
 - e) whether a basketball player has received a jersey or not.
 - f) the first initial of a basketball player's first name.
5. a) What is the difference between a primitive data type and an abstract data type?
b) What is the difference between a class and an object?
6. Assume a class named `Team` defines a sports team.
 - a) Methods define the actions in a class and typically include action words in their name. For example, `getTeamName` is a method name that returns the name of the team. List three more possible method names for the `Team` class.
 - b) List three possible object names of type `Team`.
7. The `java.util` package contains a class named `Random`. Write a statement that makes the `Random` class accessible to an application.
8. What is the value of each of the following expressions?
 - a) $5 + 7 - 3$
 - b) $10 * 2 - 3$
 - c) $10 * (2 - 3)$
 - d) $8 - 3 * 2$
 - e) $10 / 5 * 4$
 - f) $10 / 2 + 3$
 - g) $6 \% 3 + 4$
 - h) $12 \% 5 * 3$
 - i) $12 \% (5 * 3)$
9. What is the result of the following expression when `x` is 2005? When `x` is 1776? When `x` is 39?
$$(x/10)\%10$$
10. Write each equation as a valid Java expression:
 - a) $A = lw$ (geometry)
 - b) $P = \frac{R - C}{N}$ (business)
 - c) $A = \frac{h(b_1 + b_2)}{N}$ (geometry)
 - d) $V = \frac{4}{3}\pi r^3$ (geometry)
 - e) $A = \frac{F+S+T}{3}$ (algebra)
 - f) $P = \frac{5F}{4d^2}$ (physics)
 - g) $A = P + Pr t$ (business)
11. Using the following declarations, rewrite the statements to include the appropriate type casting, rounding where necessary. If type casting is not necessary, explain why:

```
int j = 5;
double k = 1.6;
int y;
double z;
```

 - a) $y = j * k;$
 - b) $z = j * k;$

- c) `z = k * k;`
d) `j = k;`
e) `k = j;`
f) `y = j + 3;`
12. Compare the way the / and % operators perform to the effects of type casting.
13. Rewrite the statements below using the appropriate assignment operator:
- `total = total + 10;`
 - `numStones = numStones - 1;`
 - `days = days % 24;`
 - `price = price * 1.2;`
14. Determine if each of the following are better represented by a variable or a constant and then write declarations using appropriate data types and descriptive identifiers:
- the number of votes received by an election candidate
 - the percentage of votes won by a candidate
 - the first, middle, and last initials of an election candidate
 - the year of the election
15. Determine if each of the following segments of code contain a syntax error, logic error, or runtime error. Explain.
- `duble salary;`
 - `int numHats`
 - `length == 12;`
 - `int test1 = 90;`
`int test2 = 85;`
`double avg;`
`avg = test1 + test2 / 2;`
 - `double x = 12;`
`double y = 0;`
`double z;`
`z = x / y;`
 - `double payCheck = 120.00;`
`NumberFormat money =`
`NumberFormat.getInstance();`
`System.out.println(money.format(payCheck));`

True/False

16. Determine if each of the following are true or false. If false, explain why.
- An identifier can contain spaces.
 - Data of type `double` is sometimes referred to as floating point.
 - An abstract data type is also called a primitive data type.

Exercises

Exercise 1

ObjectHeight

The height of an object at any given time dropped from a starting height of 100 meters is given by the equation $h=100-4.9*t^2$ where t is the time in seconds. Create an ObjectHeight application that prompts the user for a time less than 4.5 seconds and then displays the height of the object at that time. The application output should look similar to:

```
Enter a time less than 4.5 seconds: 2
The height of the object is: 80.4 meters
```

Exercise 2

PizzaCost

The cost of making a pizza at a local shop is as follows:

- Labor cost is \$0.75 per pizza, regardless of size
- Rent cost is \$1.00 per pizza, regardless of size
- Materials is $\$0.05 * \text{diameter} * \text{diameter}$ (diameter is measured in inches)

Create a PizzaCost application that prompts the user for the size of a pizza and then displays the cost of making the pizza. The application output should look similar to:

```
Enter the diameter of the pizza in inches: 10
The cost of making the pizza is: $6.75
```

Exercise 3

CollegeCalculator

In small groups brainstorm all the expenses involved in attending a college or university (rent, tuition, books, etc) and possible offset costs (scholarships, etc). Create a CollegeCalculator application that prompts the user for the amount of each expense and offset cost. If the cost is not applicable the user should enter a value of 0. Add the expenses and subtract the offset costs to determine how much money an individual will need for their school year. College websites can be used as a guide to determine relevant and appropriate expenses.

Exercise 4

JavaTerminology

Modify the JavaTerminology application created in Chapter 3, Exercise 8 to include five words from the vocabulary list in this chapter and the corresponding definition. Place each word on a separate line followed by the definition. Place a blank line between entries.

Exercise 5

Energy

Einstein's famous formula, $e=mc^2$, gives the amount of energy released by the complete conversion of matter of mass m into energy e . If m represents the mass in kilograms and c represents the speed of light in meters per second (3.0×10^8 m/s), then the result is in the energy units Joules. It takes 360000 Joules to light a 100-watt light bulb for an hour. Create an Energy application that prompts the user for a mass in kilograms and then displays the energy and the number of light bulbs that could be powered. The application output should look similar to:

```
Enter the mass in kilograms: 1
The energy produced in Joules is = 9.0E16
The number of 100-watt light bulbs powered = 2.5E11
```

Exercise 6

Change

Create a Change application that prompts the user for an amount less than \$1.00 and then displays the minimum number of coins necessary to make the change. The change can be made up of quarters, dimes, nickels, and pennies. The application output should look similar to:

```
Enter the change in cents: 212
The minimum number of coins is:
Quarters: 8
Dimes: 1
Nickels: 0
Pennies: 2
```

Exercise 7

Digits

Modify the Digits application created in a review earlier in this chapter to show the hundreds-place digit of a three digit number. The application output should look similar to:

```
Enter a three-digit number: 258
The hundreds-place digit is: 2
The tens-place digit is: 5
The ones-place digit is: 8
```

Exercise 8

DivAndMod

Create a DivAndMod application that prompts the user for two integers and then displays the result of integer and modulus division in either order. The application output should look similar to:

```
Enter an integer: 14
Enter a second integer: 4
14 / 4 = 3
14 % 4 = 2
4 / 14 = 0
4 % 14 = 4
```

Exercise 9

TimeConversion

Create a TimeConversion application that prompts the user for a time in minutes and then displays the time in hours and minutes. Be sure to consider times whether the number of minutes left over is less than 10. For example, 184 minutes in hour:minute format is 3:04 (Hint: use the modulus operator). The application output should look similar to:

```
Enter the time in minutes: 135
The time is: 2:15
```

Exercise 10

Sleep

Create a Sleep application that calculates the number of hours of your life that you have spent sleeping. Assume that you sleep 8 hours each night. To simplify the problem, assume that there are 30 days in each month and 365 days in each year. The application output should look similar to:

```
Enter your birthdate:
Year: 1990
Month: 9
Day: 8
Enter today's date:
Year: 2006
Month: 2
Day: 12
You have been alive for 5,634 days.
You have slept 45,072 hours.
```

Exercise 11

Order

A fast food restaurant charges \$1.69 for burgers, \$1.09 for fries, and \$0.99 for sodas.

- Create an Order application that prompts the employee for the number of burgers, fries, and sodas and then displays the total, the tax (6.5%), and the final cost. The application output should look similar to:

```
Enter the number of burgers: 2
Enter the number of fries: 5
Enter the number of sodas: 5
Total before tax: $13.78
Tax: $0.90
Final total: $14.68
```

- Modify Order to prompt the employee for the amount tendered and then display the change due. Application output should look similar to:

```
Enter amount tendered: $20.00
Change: $5.32
```

Exercise 12

Project

Create a Project application to help analyze the time taken for a Java project. The application should prompt you for the time spent designing, coding, debugging, and testing, and then displays a table showing the percentage of time taken for each part. The application output should look similar to:

Enter the number of minutes spent on each of the following project tasks:

Designing: 120

Coding: 240

Debugging: 30

Testing: 30

Task	% Time
Designing	28.57 %
Coding	57.14 %
Debugging	7.14 %
Testing	7.14 %

Exercise 13

Spending

Create a Spending application to help examine the spending patterns of a user. The application should prompt the user for the amount spent last month on food, clothing, entertainment, and rent, and then displays a table showing the percentage of expenditures in each category. The application output should look similar to:

Enter the amount spent last month on the following items:

Food: \$250

Clothing: \$250

Entertainment: \$250

Rent: \$1250

Category	Budget
Food	12.50 %
Clothing	12.50 %
Entertainment	12.50 %
Rent	62.50 %

Exercise 14

CollegeCalculator

In small groups brainstorm all the expenses involved in attending a college or university (rent, tuition, books, etc) and possible offset costs (scholarships, etc). Create a CollegeCalculator application that prompts the user for the amount of each expense and offset cost. If the cost is not applicable the user should enter a value of 0. Add the expenses and subtract the offset costs to determine how much money an individual will need for their school year. College websites can be used as a guide to determine relevant and appropriate expenses.

Exercise 15

SimpleInterest

There are two kinds of interest: simple and compound. With simple interest, the amount of the deposit remains the same, and the amount of interest is paid at the end of a time interval. For example, if \$1,000 is deposited for 7 years at an interest rate of 6% per year, \$60 will be deposited at the end of each year, for a total of \$1,420 after 7 years.

- The value of the amount after the term is calculated using the formula:

$$\text{Amount} = \text{Principal} * (1 + \text{years} * \text{interest rate})$$

Create a SimpleInterest application that prompts the user for the principal, number of years, and the interest rate (as a fraction) and then calculates the amount of interest. The application should display output similar to:

```
Enter the principal: 5000
Enter the number of years: 5
Enter the interest rate: .06
The value after the term is: $6,500.00
```

- The formula in part (a) can be adjusted to calculate what principal will need to be invested in order to have a certain amount of money after a specified term and interest rate:

$$\text{Principal} = \text{Amount} / (1 + \text{years} * \text{interest rate}).$$

Modify SimpleInterest to prompt the user for the desired amount, number of years, and interest rate and then calculate the principal that will need to be invested.

Exercise 16

Election

The results of a primary election between two candidates in three states are:

	Awbrey	Martinez
New York	314159	271860
New Jersey	89008	121032
Connecticut	213451	231034

Write a program that prompts the user for the election results, and then displays output similar to:

Candidate	Votes	Percentage
Awbrey	616618	49.71 %
Martinez	623926	50.29 %
TOTAL VOTES:	1240544	

SAMPLE

Chapter 5

Conditional Control Structures

Statements that branch to perform one action or another depending on a condition are used to give an application decision-making capabilities. This chapter focuses on the `if` and `switch` conditional control structures.

The if Statement

conditional control structure

The `if` statement is a *conditional control structure*, also called a *decision structure*, which executes a set of statements when a condition is true. Conditional control structures are used to change program flow. The `if` statement takes the form:

```
if (<condition>) {  
    <statements>  
}
```

TIP Using `=` instead of `==` in an `if` statement condition generates an error.

For example, in the following `if` statement, `guess == 7` is the condition, and there is one statement that will be executed when this condition is true:

```
if (guess == SECRET_NUM) {  
    System.out.println("You guessed it!");  
}
```

The `==` relational operator determines if the value of `guess` is equal to the value of `SECRET_NUM`. If equal, the `println()` statement executes. If not, then program flow continues to the next statement after the closing brace of the `if` statement.

The condition of an `if` statement is a *Boolean expression*, which evaluates to either `true` or `false`. *Relational operators* can be used to form Boolean expressions. There are six relational operators:

Boolean expression
relational operators

Comparing Objects

Because objects point to a location in memory, rather than directly storing a value, they cannot be compared using built-in relational operators. A class defines methods that are used to compare objects.

Operator	Meaning
<code>==</code>	equal
<code><</code>	less than
<code><=</code>	less than or equal
<code>></code>	greater than
<code>>=</code>	greater than or equal
<code>!=</code>	not equal

A boolean variable may also be used as the condition of an `if` statement because its value is `true` or `false`. For example, in the following statements, the message is displayed:

```
boolean gameOver = true;
if (gameOver) {
    System.out.println("Thanks for playing!");
}
```

Roundoff Error

The condition of an `if` statement should never make an equality comparison between floating point numbers because of the possibility of roundoff error. A *roundoff error* occurs when a floating point number cannot be exactly represented in binary notation by the computer. For example, the decimal number 0.8 is a repeating decimal in binary form (0.1100110011...). Since there are only a finite number of bits in memory that can be used to represent a number, a repeating decimal must be rounded off, preventing an exact representation.

For example, consider the following statements:

```
if ((4.80 * 100 - 480) == 0) {
    System.out.println("Zero.");
}
```

The condition seems to evaluate to `true`. However, the number 4.80 cannot be exactly represented in binary. Therefore, when 4.80 is multiplied by 100 the result is slightly different from 480. This difference is due to roundoff error. In this case, subtracting 480 from 4.80×100 results in a very small number that is not equal to 0 ($-1.77635683940025E-14$). The following statements are one way to take into consideration possible roundoff error:

```
final double VERY_SMALL_VALUE = 0.000001
if ((4.80 * 100 - 480) < sngVERY_SMALL_VALUE) {
    System.out.println("Zero.");
}
```

Review: SurfsUp – part 1 of 3

Create a *SurfsUp* application that prompts the user for the wave height and then displays “Great day for surfing!” when the waves are 6 feet and over.

The if-else Statement

The `if` statement can include an optional `else` clause that is executed when the `if` condition evaluates to false. The `if-else` statement takes the following form:

```
if (<condition>) {
    <statements>
} else {
    <statements>
}
```

For example, in the following `if-else` statement, different messages are displayed for correct and incorrect guesses:

```
if (guess == SECRET_NUM) {  
    System.out.println("You guessed it!");  
} else {  
    System.out.println("Try again.");  
}
```

The indentation and organization of the `if-else` is important for readability. The structure shown is a code convention that clearly indicates the actions for a true condition and the actions for a false condition.

Review: SurfsUp – part 2 of 3

Modify the SurfsUp application to display “Great day for surfing!” when the waves are 6 feet or over and “Go body boarding!” when the waves are less than 6 feet.

Review: CircleCircumference – part 2 of 2

Modify the CircleCircumference application from Chapter 4 so that the message “Negative radii are illegal.” is displayed if a negative number is entered by the user for the radius value. Otherwise the application should calculate and display the circumference of the circle.

Nested Statements

An `if-else` statement can contain another `if-else` or `if` statement. Statements placed within the same type of statements are called *nested*. For example, the nested `if-else` gives a hint when the user does not guess the correct number:

```
if (guess == SECRET_NUM) {      //correct  
    System.out.println("You guessed it!");  
} else {  
    if (guess < SECRET_NUM) {    //too low  
        System.out.println("Too low.");  
    } else {  
        //too high  
        System.out.println("Too high.");  
    }  
}
```

Carefully indenting the statements makes it clear which are nested.

Review: Stages

Create a Stages application that prompts the user for an age. For an age over 18, `adult` is displayed. For an age less than or equal to 18, `toddler` is displayed when the age is less than or equal to 5, `child` when the age is less than or equal to 10, `preteen` when the age is less than or equal to 12, and `teen` when the age is over 12.

The if-else if Statement

The `if-else if` statement is used to decide among three or more actions and takes the form:

```
if (<condition>) {  
    <statements>  
} else if (<condition>) {  
    <statements>  
} else {  
    <statements>  
}
```

There can be multiple `else if` clauses, and the last `else` clause is optional. For example, there are three possible decisions in the `if-else if` statement below:

```
if (guess == SECRET_NUM) {           //correct  
    System.out.println("You guessed it!");  
} else if (guess < SECRET_NUM) {     //too low  
    System.out.println("Too low.");  
} else {                           //too high  
    System.out.println("Too high.");  
}
```

The logic used in developing an `if-else if` statement is important. For example, when testing a range of numbers, `if` conditions must be properly ordered because statements are executed for the first true condition only and then program flow continues to the next statement after the `if-else if`.

When choosing between nested `if-else` statements and a single `if-else if` statement, the `if-else if` allows only one branch to execute and the conditions show a clear sequence. In general, the `if-else if` statement is easier to read and understand.

Review: SurfsUp – part 3 of 3

Modify the SurfsUp application to display “Great day for surfing!” when the waves are 6 feet or over, “Go body boarding!” when the waves are between 3 and 6 feet, “Go for a swim.” when the waves are from 0 to 3 feet, and “Whoa! What kind of surf is that?” otherwise.

Review: Discriminant

In mathematics, the quantity $b^2 - 4ac$ is called the “discriminant.” Create a Discriminant application that prompts the user for the values of a , b , and c and then displays “No roots” if the discriminant is negative, “One root” if the discriminant is zero, and “Two roots” if the discriminant is positive. Application output should look similar to:

```
Enter the value for a: 7  
Enter the value for b: -9  
Enter the value for c: 2  
Two roots
```

The switch Statement

The `switch` statement is a conditional control structure that uses the result of an expression to determine which statements to execute. The `switch` statement is sometimes preferable to the `if-else if` statement because code may be easier to read. The `switch` statement takes the form:

```
switch (<integer expression>) {  
    case x:  
        <statement>;  
        break;  
    ...  
    default:  
        <statements>;  
        break;  
}
```

case The expression must evaluate to an integer. There can be multiple `case` clauses. The `break` statement is necessary to move program control to the next statement after the `switch` statement. The `default` code is optional and is executed when none of the previous cases are met. For example, when `score` is 5, the `case 5` statement executes and then program control moves to the next statement after the `switch` (skipping the `case 10` statement):

```
switch (score) {  
    case 0: System.out.println("Better luck next time."); break;  
    case 5: System.out.println("Pretty good."); break;  
    case 10: System.out.println("Great!"); break;  
}
```

If the `break` statement is not included in a `case` clause, execution continues on to the next statement within the `switch` statement. This can be useful when the same set of statements applies to more than one situation:

```
switch (score) {  
    case 0: System.out.println("Better luck next time."); break;  
    case 1:  
    case 2:  
    case 3:  
    case 4:  
    case 5: System.out.println("Pretty good."); break;  
    case 6:  
    case 7:  
    case 8:  
    case 9:  
    case 10: System.out.println("Great!"); break;  
}
```

In this statement, “Pretty good.” is displayed when the score is 1, 2, 3, 4, or 5. Scores 6 though 10 display “Great”.

Review: Hurricane

The Saffir-Simpson Hurricane Scale provides a rating (a category) depending on the current intensity of a hurricane. Create a Hurricane application that displays the wind speed for the hurricane category entered by the user. Display the speed in miles per hour (mph), knots (kts), and kilometers per hour (km/hr). Refer to the Saffir-Simpson Hurricane Scale below for wind speeds:

- Category 1: 74-95 mph or 64-82 kt or 119-153 km/hr
- Category 2: 96-110 mph or 83-95 kt or 154-177 km/hr
- Category 3: 111-130 mph or 96-113 kt or 178-209 km/hr
- Category 4: 131-155 mph or 114-135 kt or 210-249 km/hr
- Category 5: greater than 155 mph or 135 kt or 249 km/hr

Generating Random Numbers

Linear Congruential Method

pseudorandom

Random class

Games, simulators, screen savers, and many other types of applications make use of random numbers. A widely used method for generating random numbers is called the *Linear Congruential Method*. This method uses a formula to generate a sequence of numbers. Although the numbers in the sequence vary and for most applications can be considered random, the sequence will at some point repeat. Therefore, random numbers in a computer application are referred to as *pseudorandom* (like random).

Java includes the Random class in the java.util package for generating random numbers. This class uses the Linear Congruential Method. Some of the Random class methods include:

Class Random (java.util.Random)

Methods

nextInt()	returns the next random integer in the random number generator's sequence.
nextInt(int n)	returns the next random integer between 0 (inclusive) and n in the random number generator's sequence.
nextDouble()	returns the next random double between 0.0 and 1.0 in the random number generator's sequence.

The RandomNumberDemo class below instantiates a Random object and displays the first five numbers between 0 and 100 in its sequence:

```
public class RandomNumberDemo {  
  
    public static void main(String[] args) {  
        Random r = new Random();  
  
        System.out.println("First number: " + r.nextInt(100));  
        System.out.println("Second number: " + r.nextInt(100));  
        System.out.println("Third number: " + r.nextInt(100));  
        System.out.println("Fourth number: " + r.nextInt(100));  
        System.out.println("Fifth number: " + r.nextInt(100));  
    }  
}
```

RandomNumberDemo produces output similar to the following:

```
First number: 13
Second number: 80
Third number: 93
Fourth number: 90
Fifth number: 46
```

random numbers in a range

To generate a random number in a range with a minimum value greater than 0, the following formula is used:

```
r.nextInt(highNum - lowNum + 1) + lowNum
```

A similar formula can be used to generate random doubles in a range:

```
(highNum - lowNum + 1) * r.nextDouble() + lowNum
```

seed

The Linear Congruential Method requires a *seed*, which is a starting value, for calculating a sequence of numbers. Java automatically generates this seed when a new Random object is instantiated. However, if a seed value is specified, the same sequence of “random” numbers will be generated each time the program is run. This can be useful for debugging. After the program has been tested, remove the seed so that the sequence of generated numbers vary each time the application runs. For example, the code below specifies a seed. Two runs of the application are displayed:

```
public class RandomNumberDemo {

    public static void main(String[] args) {
        Random r = new Random(10);

        System.out.println("First number: " + r.nextInt(100));
        System.out.println("Second number: " + r.nextInt(100));
        System.out.println("Third number: " + r.nextInt(100));
        System.out.println("Fourth number: " + r.nextInt(100));
        System.out.println("Fifth number: " + r.nextInt(100));

    }
}
```

first run:

```
First number: 17
Second number: 71
Third number: 98
Fourth number: 34
Fifth number: 64
```

second run:

```
First number: 17
Second number: 71
Third number: 98
Fourth number: 34
Fifth number: 64
```

Two runs of RandomNumberDemo using the same seed.

Note that both runs generate the same sequence of numbers.

Review: RandomNum

Create a RandomNum application that prompts the user for two numbers. The first number is a minimum value and the second is a maximum value. RandomNum then displays an integer between the min and max values entered by the user.

Compound Boolean Expressions

&& and || logical And

logical Or

Conditions with complex criteria are formed using the `&&` and `||` operators. The `&&` operator is called the *logical And*. It is used to form an expression that evaluates to true only when both operands are also true. The `||` operator is called the *logical Or*. An expression formed with this operator evaluates to true when either operand is true. For example, the following statement tests for invalid guesses:

```
if (guess < 1 || guess > 50) {           //invalid guess
    System.out.println("Invalid guess.");
} else if (guess == SECRET_NUM) {         //correct guess
    System.out.println("You guessed it!");
}
```

TIP The `|` key is located above the Enter key on most standard keyboards.

When a guess is either less than 1 *or* greater than 50, “Invalid guess.” is displayed. Note that the expression also evaluates to true when both operands are true. The condition in the `if` statement is called a *compound Boolean expression* because more than one Boolean expression determines whether the condition is true or false.

truth table

How a compound Boolean expression evaluates with `&&` and `||` operators can be shown with truth tables. A *truth table* shows the possible outcomes of compound Boolean expressions:

And			Or		
Exp1	Exp2	Result	Exp1	Exp2	Result
True	True	True	True	True	True
True	False	False	True	False	True
False	True	False	False	True	True
False	False	False	False	False	False

As another example, consider an application that computes a discount depending on the item and quantity purchased:

```
if (itemNum == 873 && quantity > 50) { //more than 50 of 873
    discount = 1;                         //$.1 discount
}
```

This `if` statement executes the `discount = 1` statement if item number is 873 *and* quantity is greater than 50.

A third operator is `!`. The `!` operator is called the *logical Not*. An expression including `!` is evaluated according to the following truth table:

Not	
Exp	Result
True	False
False	True

For example, the following statements display a message when the item number is *not* 873:

```
if (!itemNum == 873) {           //any item EXCEPT 873
    System.out.println("No discount given.");
}
```

short circuit evaluation

Java uses short-circuit evaluation for determining the result of a compound Boolean expression that includes `&&` or `||`. In *short-circuit evaluation*, the left operand is evaluated first. If the result of the entire expression can be determined by the value of the left operand, then no other operands will be evaluated. For example, the expression `x < 0 || x > 5` evaluates to `true` if `x` is less than 0 regardless of the value of `x > 5`. Therefore, when `x` is less than 0, the second operand will not be evaluated. As another example, the expression `x > 5 && x < 20` evaluates to `false` if `x` is less than or equal to 5 regardless of the value of `x < 20`. Therefore, when `x` is less than or equal to 5, the second operand will not be evaluated.

order of operations

In the order of operations, `!` is evaluated before `&&`. `||` is evaluated last. For example, the expression `!5 < 6 || 2 > 4 && 3 < 6` evaluates to `false` because `!5 < 6` is performed first, then `2 > 4 && 3 < 6`, and then `False || False`. Use parentheses to change operator precedence and to make code more readable.

Review: Delivery

Create a Delivery application that prompts the user for the length, width, and height of a package, and then displays “Reject” if any dimension is greater than 10, and “Accept” if all the dimensions are less than or equal to 10.

The Math Class

java.lang

TIP The Math class also contains the double constant `PI` that approximates π .

Java includes the Math class in the `java.lang` package for performing math functions such as exponentiation and square root. The Math class contains numerous methods, which include:

Class Math (`java.lang.Math`)

Methods

`abs(num)` returns the absolute value of `num`, which can be an `int` or a `double` value.

`pow(double num1, double num2)`

returns the `num1` raised to the `num2` power.

`sqrt(double num)`

returns the square root of `num`, where `num` is a positive number.

Calling a Math method requires using the class name. For example, `Math.abs(-3)` returns 3. The application on the next page demonstrates the Math methods:

```

import java.lang.Math;

public class TestMathMethods {

    public static void main(String[] args) {
        int posNum = 12, negNum = -12;
        int num1 = 2, num2 = 6;
        int square = 49;

        System.out.println("The absolute value of " + posNum
                           + " is " + Math.abs(posNum));
        System.out.println("The absolute value of " + negNum
                           + " is " + Math.abs(negNum));
        System.out.println(num1 + " raised to the " + num2
                           + " power is " + Math.pow(num1, num2));
        System.out.println("The square root of " + square
                           + " is " + Math.sqrt(square));
    }
}

```

The TestMathMethods produces the following output:

```

The absolute value of 12 is 12
The absolute value of -12 is 12
2 raised to the 6 power is 64.0
The square root of 49 is 7.0

```

Review: PerfectSquare

Create a PerfectSquare application that prompts the user for an integer and then displays a message indicating whether or not the number is a perfect square. This can be determined by finding the square root of a number, truncating it (by casting the `double` result), and then squaring that result.

Chapter 5 Case Study

In this case study, a computerized version of the Rock Paper Scissors game will be created. Rock Paper Scissors is a popular game played between two individuals for decision making or just for competitive fun. The rules of the game are Rock dulls Scissors (Rock wins), Scissors cuts Paper (Scissors wins), and Paper covers Rock (Paper wins). The two players make a “throw” at the same time. The hand signals thrown by the players are then compared to the rules of the game to determine the winner. In the computerized version, the user plays against the computer.

RPS Specification

RPS is played between the computer and a single player. The player is prompted for a throw where 1 corresponds to Rock, 2 to Paper, and 3 to Scissors. A random number between 1 and 3 is generated for the computer throw. The winner is determined based on the rules of Rock Paper Scissors.

The RPS interface should be simple. The user will be prompted to enter an integer between 1 and 3, where 1 represents Rock, 2 represents Paper, and 3 represents Scissors. The program then generates a random number between 1 and 3, displays the generated number and the player's number and determines a winner.

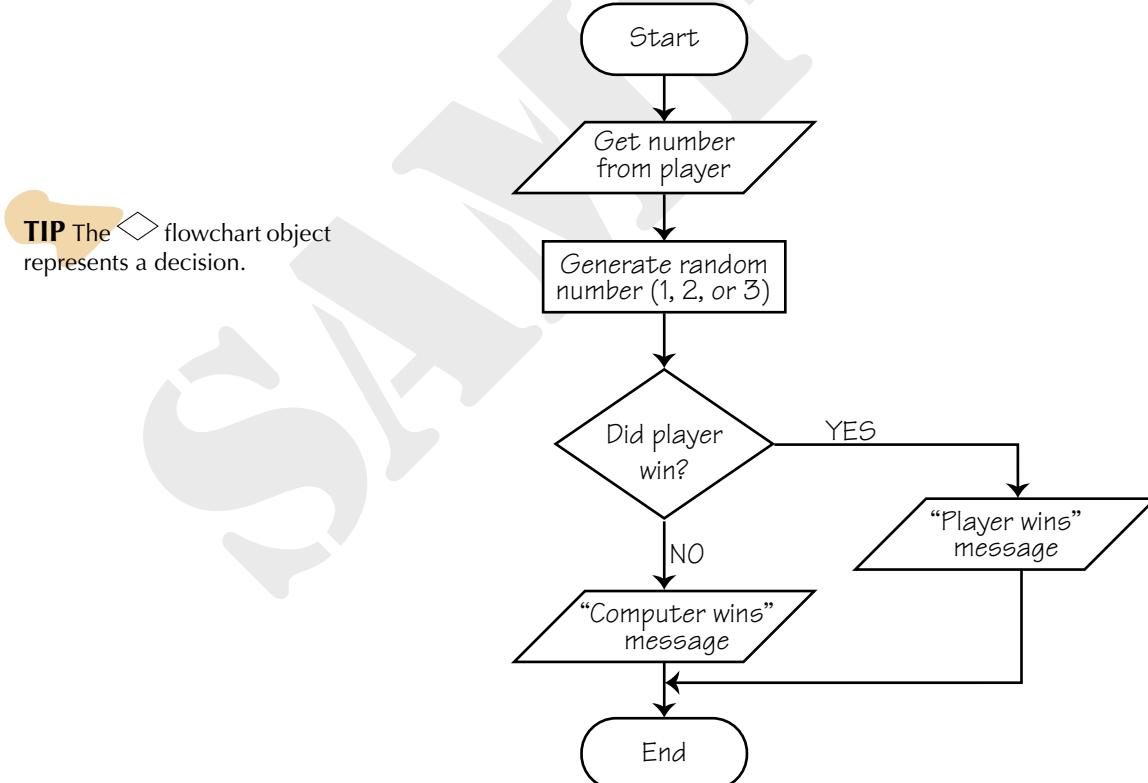
The RPS output sketch:

```
Enter your throw (1=Rock, 2=Paper, 3=Scissors): 3
Player throws SCISSORS.
Computer throws PAPER.
Player wins!
```

The RPS algorithm:

1. Prompt the user for a number between 1 and 3.
2. Generate a random number between 1 and 3.
3. Compare the generated number to the number typed by the user.
4. Determine a winner and display an appropriate message.

The RPS flowchart:



RPS Code Design

The input for RPS is a number typed by the user. An integer variable to store the user's input will be needed.

The output for RPS is a message with the user's input, the generated number, and the winner.

Data generated by RPS is a random integer between 1 and 3, which represents the computer's "throw." An `int` variable to store the computer-generated number will be needed. Other data used in this application can be represented by `int` constants that represent Rock (1), Paper (2), and Scissors(3).

Based on the algorithm and flowchart, the code design for the RPS application will include decision structures to compare the user's input to the number generated by the computer. This comparison can be done with either a `switch` statement or `if-else if` statements. For this implementation, an `if-else if` will be used. A pseudocode algorithm for RPS follows:

```
Prompt user for a number (1=Rock, 2=Paper, 3=Scissors)
Generate a random number between 1 and 3, inclusive
Display a message with player's number and computer's number
if (playerThrow == 1 and computerThrow == 1)
    Draw message
else if (playerThrow == 1 and computerThrow == 2)
    Computer wins message
else if (playerThrow == 1 and computerThrow == 3)
    Player wins message
if (playerThrow == 2 and computerThrow == 1)
    Player wins message
else if (playerThrow == 2 and computerThrow == 2)
    Draw message
else if (playerThrow == 2 and computerThrow == 3)
    Computer wins message
if (playerThrow == 3 and computerThrow == 1)
    Computer wins message
else if (playerThrow == 3 and computerThrow == 2)
    Player wins message
else if (playerThrow == 3 and computerThrow == 3)
    Draw message
```

RPS Implementation

Based on the code design, the RPS implementation follows:

```
/*
 * RPS.java
 */

import java.util.Scanner;
import java.util.Random;

/**
 * Plays Rock Paper Scissors against one player.
 */
public class RPS {

    public static void main(String[] args) {
        final int ROCK = 1, PAPER = 2, SCISSORS = 3;
        int playerThrow, computerThrow;
        Scanner input = new Scanner(System.in);
        Random rand = new Random();
```

```

/* prompt player for throw and read number typed */
System.out.print("Enter your throw (1=Rock, 2=Paper, 3=Scissors): ");
playerThrow = input.nextInt();
input.close();

/* Generate computer throw */
computerThrow = rand.nextInt(3) + 1; /* random integer between 1 and 3 */

/* Inform player of throws */
System.out.print("Player throws ");
switch (playerThrow) {
    case ROCK: System.out.println("ROCK."); break;
    case PAPER: System.out.println("PAPER."); break;
    case SCISSORS: System.out.println("SCISSORS."); break;
}
System.out.print("Computer throws ");
switch (computerThrow) {
    case ROCK: System.out.println("ROCK."); break;
    case PAPER: System.out.println("PAPER."); break;
    case SCISSORS: System.out.println("SCISSORS."); break;
}

/* Determine winner */
if (playerThrow == ROCK && computerThrow == ROCK) {
    System.out.println("It's a draw!");
} else if (playerThrow == ROCK && computerThrow == PAPER) {
    System.out.println("Computer wins!");
} else if (playerThrow == ROCK && computerThrow == SCISSORS) {
    System.out.println("Player wins!");
}

if (playerThrow == PAPER && computerThrow == ROCK) {
    System.out.println("Player wins!");
} else if (playerThrow == PAPER && computerThrow == PAPER) {
    System.out.println("It's a draw!");
} else if (playerThrow == PAPER && computerThrow == SCISSORS) {
    System.out.println("Computer wins!");
}

if (playerThrow == SCISSORS && computerThrow == ROCK) {
    System.out.println("Computer wins!");
} else if (playerThrow == SCISSORS && computerThrow == PAPER) {
    System.out.println("Player wins!");
} else if (playerThrow == SCISSORS && computerThrow == SCISSORS) {
    System.out.println("It's a draw!");
}
}
}
}

```

The RPS application output looks similar to:

```

Enter your throw <1=Rock, 2=Paper, 3=Scissors>: 2
Player throws PAPER.
Computer throws ROCK.
Player wins!

```

RPS Testing and Debugging

This case study should test all possible throw combinations. To do this, a seed can be used so that the same random number is generated from run to run. By varying only the player input from run to run, each of the combinations can be tested. To specify the seed, the Random object is instantiated with an integer argument:

```
Random rand = new Random(3);
```

Note that any number will work for the seed. The point is to use a seed so that the same random number is generated from run to run. Running the application with a seed reduces the number of factors to consider when testing. Three runs using the same seed look similar to:

```
Enter your throw (1=Rock, 2=Paper, 3=Scissors): 1
Player throws ROCK.
Computer throws SCISSORS.
Player wins!
```

```
Enter your throw (1=Rock, 2=Paper, 3=Scissors): 2
Player throws PAPER.
Computer throws SCISSORS.
Computer wins!
```

```
Enter your throw (1=Rock, 2=Paper, 3=Scissors): 3
Player throws SCISSORS.
Computer throws SCISSORS.
It's a draw!
```

Different seeds can be used until all combinations are tested. Note that this application has a small and limited number of combinations to test. Other methods of testing will be discussed as applications become more complex.

Testing also involves considering user input and exception handling. What happens when the player enters 4? How should illegal input be handled? Preventing input errors and exception handling are discussed later in the text.

Review: RPS – part 1 of 2

Modify the RPS Chapter 5 Case Study to use nested `if-else` statements rather than `if-else if` statements to determine the winner.

Review: RPS – part 2 of 2

Modify the RPS Chapter 5 Case Study to use a `switch` statement to determine the winner. (Hint: You may need an `if-else if` statement within the `case` statements.)

Chapter Summary

This chapter introduced conditional control structures, random numbers, and logical operators. Conditional control structures, also called decision structures, include the `if` and `switch` statements. The `if` uses the result of a Boolean expression to determine program flow, and the `switch` uses the result of an integer expression to determine program flow.

In the `if` statement, program flow branches to a set of statements when the condition evaluates to `true`. In the `if-else` statement, program flow branches to one set of statements for a `true` condition and a different set when the condition is `false`. Nested `if-else` statements can be used for even more control over program flow. The `if-else if` is used to decide among three or more actions.

Relational operators can be used to form a Boolean expression. They include the `=`, `<`, `<=`, `>`, `>=`, and `!=` operators. Two or more Boolean expressions can be joined with logical operators to form a compound Boolean expression. Logical operators include `&&` (logical And), `||` (logical Or), and `!` (logical Not). A truth table shows how a compound Boolean expression evaluates.

Roundoff error occurs when a floating point number cannot be exactly represented in binary notation by the computer. Therefore equality comparisons between floating point numbers should not be made.

The `switch` statement contains multiple `case` clauses. A `break` statement is required to move program control out of the `switch` statement.

Java uses the Linear Congruential Method to generate a sequence of random numbers. Because the sequence eventually repeats, random number in a computer application are really pseudorandom. Java includes the `Random` class in the `java.util` package for generating random numbers. If a seed value is specified, a `Random` object will generate the same sequence of random numbers each time the application is run.

The `Math` class, part of the `java.lang` package, contains many useful methods for performing math functions. Calling a `Math` method requires including the class name.

Code conventions introduced in this chapter are :

- The clauses of an `if` statement should be indented.
- nested `if` statements should be indented.
- The `case` clause of a `switch` statement should be indented.

Vocabulary

Boolean expression An expression that evaluates to true or false.

Compound Boolean expression An expression that includes more than one Boolean expression.

Conditional control structure A statement that branches program flow depending on a condition. Also called a decision structure.

Decision structure see Conditional control structure.

Linear Congruential Method A method that uses a formula to generate a sequence of pseudorandom numbers.

Logical And The `&&` operator used to form a compound Boolean expression.

Logical Not The `!` operator used to reverse the value of a Boolean expression.

Logical Or The `||` operator used to form a compound Boolean expression.

Nested A statement placed within the same type of statement.

Pseudorandom Not truly random, but like random.

Relational operator Operators (`=`, `<`, `<=`, `>`, `>=`, `!=`) that can be used to form a Boolean expression.

Roundoff error An error that occurs when a floating point number cannot be exactly represented in binary notation by the computer.

Seed A starting value for calculating a sequence of random numbers.

Short circuit evaluation A process for determining the result of a Boolean expression where the left operand is evaluated first. If the result of the entire expression can be determined by the left operand, no other operands are evaluated.

Truth table A table that shows the possible outcomes of two expressions joined by a logical operator.

`==` The equality relational operator.
`<` The less than relational operator.
`<=` The less than or equal relational operator.
`>` The greater than relational operator.
`>=` The greater than or equal relational operator.
`!=` The not equal relational operator.
`&&` The logical And operator.
`||` The logical Or operator.
`!` The logical Not operator.

`break` A statement that moves program control to the next statement after the current structure.

`case` A clause in the `switch` statement that contains statements to be executed when the `case` condition matches the result of the `switch` expression.

`if` A decision structure that executes a set of statements when a condition is true.

`if-else` A decision structure that executes one set of statements when a condition is true and another set of statements when the condition is false.

`if-else if` A decision structure used to decide among three or more actions.

Math A `java.lang` class with methods for performing math functions.

`switch` A decision structure that uses the result of an expression to determine which set of statements to execute.

Random A `java.util` class with methods for generating random integers and doubles.

Critical Thinking

1. Use a decision structure to write an appropriate statement for each of the following:
 - a) Display Great job! when grade is 90 or higher.
 - b) Display Error when number is less than 20 or greater than 50.
 - c) Add 2 to the value of y when y is less than 100.
2. Assume num1 and num2 contain integer values. Write an if-else if statement that displays one of the following messages as appropriate:

First number is larger.
Second number is larger.
Numbers are equal.
3. a) Which is the appropriate word, odd or even for the blanks below?

```
if (num % 2 == 0) {  
    System.out.println("___ number");  
} else {  
    System.out.println("___ number");  
}
```

b) Rewrite the if-else as a switch statement.
4. The nextInt() method in the Random class generates a random integer between 0 and a specified maximum value. Write a formula that includes the nextInt() method for each of the following situations:
 - a) Generate a random integer between 1 and 50.
 - b) Generate a random integer between 20 and 100.
 - c) Generate a random double between 10 and 20, inclusive.
5. Identify the logic errors in the statements below, which should display a single appropriate message for any value of age:

```
if (age < 18) {  
    System.out.println("child");  
} else if (age > 18 && age < 65) {  
    System.out.println("adult");  
} else if (age > 65) {  
    System.out.println("senior");  
}
```
6. Given the following assignments, determine if each of the following expressions evaluates to true or false:

size = 100 weight = 50 value = 75

 - a) size > 50 && weight == 50
 - b) value < 100 && !(weight == 50)
 - c) size >= 100 || value >= 100
 - d) weight < 50 || size > 50
 - e) !(value < 75)
 - f) !(size > 100 && weight > 50 && value > 75)
 - g) (value < 125 || weight < 76) && size == 100
7. a) Write a statement that will calculate y^x .
b) Write a statement that will calculate the absolute value of y.
c) Write a statement that will calculate the square root of y.

True/False

8. Determine if each of the following are true or false. If false, explain why.
 - a) The condition of an if statement must be a Boolean expression.
 - b) A roundoff error can occur when comparing two integers.
 - c) A nested if statement and an if-else if statement are the same.
 - d) The expression in a switch statement must evaluate to a double.
 - e) Numbers generated by a computer program are actually pseudorandom.
 - f) Specifying a seed value results in a different sequence of "random" numbers each time the program is run.
 - g) A compound Boolean expression can contain more than two Boolean expressions.
 - h) In a logical And expression, both operands must be true for the expression to evaluate to true.
 - i) In logical expressions, && is evaluated before !.
 - j) The pow() method in the Math class is used for exponentiation.
 - k) The statement `x = abs(-3);` will return the value 3.
 - l) A diamond shaped object represents a decision in a flowchart.

Exercises

Exercise 1

Printing

Printing prices are typically based on the number of copies to be printed. For example:

0 – 99	\$0.30 per copy
100 – 499	\$0.28 per copy
500 – 749	\$0.27 per copy
750 – 1000	\$0.26 per copy
over 1000	\$0.25 per copy

Create a Printing application that prompts the user for the number of copies to print and then displays the price per copy and the total price for the job. Application output should look similar to:

```
Enter the number of copies to be printed: 1001
Price per copy is: $0.25
Total cost is: $250.25
```

Exercise 2

PackageCheck

A delivery service does not accept packages heavier than 27 kilograms or larger than 0.1 cubic meters (100,000 cubic centimeters). Create a PackageCheck application that prompts the user for the weight of a package and its dimensions (length, width, and height), and then displays an appropriate message if the package does not meet the requirements. Messages should include:

- Too heavy.
- Too large.
- Too heavy and too large.

The application output should look similar to:

```
Enter package weight in kilograms: 32
Enter package length in centimeters: 10
Enter package width in centimeters: 25
Enter package height in centimeters: 38
Too heavy.
```

Exercise 3

Eggs

A wholesale egg company bases their prices on the number of eggs purchased:

0 up to but not including 4 dozen	\$0.50 per dozen
4 up to but not including 6 dozen	\$0.45 per dozen
6 up to but not including 11 dozen	\$0.40 per dozen
11 or more dozen	\$0.35 per dozen

Extra eggs are priced at $\frac{1}{12}$ the per dozen price.

Create an Eggs application that prompts the user for the number of eggs, and then calculates the bill. The application output should look similar to:

```
Enter the number of eggs purchased: 18
The bill is equal to: $0.75
```

Exercise 4

CarRecall

An auto company produced some models of cars that may be difficult to drive because the car wheels are not exactly round. Cars with model numbers 119, 179, 189 through 195, 221, and 780 have been found to have this defect. Create a CarRecall application that prompts a customer for the model number of their car to find out if it is defective and then displays “Your car is not defective.” when the user typed a model number without a defect. Otherwise, the message “Your car is defective. It must be repaired.” should be displayed. Application output should look similar to:

```
Enter the car's model number: 191
Your car is defective. It must be repaired.
```

Exercise 5

Grade

Create a Grade application that prompts the user for the percentage earned on a test or other graded work and then displays the corresponding letter grade. The application should use the grading scale at your school or the following grading scale:

90 – 100	A
80 – 89	B
70 – 79	C
60 – 69	D
below 60	F

The application output should look similar to:

```
Enter the percentage: 80
The corresponding letter grade is: B
```

Exercise 6

MathTutor

Create a MathTutor application that displays math problems by randomly generating two numbers, 1 through 10 and an operator (*, +, -, /), and then prompts the user for an answer. The application should check the answer, display a message, and the correct answer, if necessary. The application output should look similar to:

```
What is 6 + 2? 8
Correct!
```

Exercise 7

EquivalentFractions

Create an EquivalentFractions application that quizzes the user on equivalent fractions.

- a) Display eight fractions and prompt the user to match pairs of equivalent fractions.
Application output should look similar to:

Equivalent Fractions Quiz

1. $\frac{21}{3}$
2. $\frac{2}{3}$
3. $\frac{4}{3}$
4. $\frac{28}{4}$
5. $\frac{8}{12}$
6. $1\frac{1}{3}$
7. $\frac{5}{1}$
8. $\frac{125}{5}$

```
Which fraction number is equivalent to fraction #1? #4  
Correct!
```

- b) Modify the EquivalentFractions application to display the user's score.
- c) Modify the EquivalentFractions application to have the user select a beginner or advanced mathematical level and based on their choice display a different set of fractions.

Exercise 8

RandomGenerator

Create a RandomGenerator application that implements the Linear Congruential Method. The formula used by this method is:

$$X_{n+1} = (aX_n + c) \% m$$

Use constant integers for a, c, and m. Choose a seed integer value for X_0 . Show 10 numbers from the sequence. Application output should look similar to:

```
Seed = 12, a = 1246, c = 200, m = 50

(1246*12 + 200) % 50=2
(1246*2 + 200) % 50=42
(1246*42 + 200) % 50=32
(1246*32 + 200) % 50=22
(1246*22 + 200) % 50=12
(1246*12 + 200) % 50=2
(1246*2 + 200) % 50=42
(1246*42 + 200) % 50=32
(1246*32 + 200) % 50=22
(1246*22 + 200) % 50=12
```

Note the sequence shown in the output repeats after five numbers. Experiment by changing the values for a, c, m, and X_0 (the seed) to see which values create the most "random" sequence of numbers (the largest set of nonrepeating numbers).

Exercise 9

GuessingGame

The GuessingGame is a number guessing game played between the computer and one player. The GuessingGame algorithm follows:

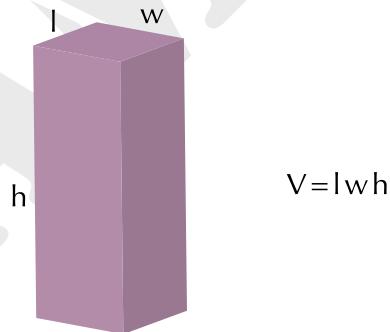
1. Determine a secret number between 1 and 20.
 2. Prompt the player for a number between 1 and 20.
 3. Compare the player's number to the secret number.
 4. Display the secret number and the player's number.
 5. If the player's number matches the secret number, then display a "You won!" message.
Otherwise display a "Better luck next time." message.
- a) Draw a GuessingGame flowchart based on the algorithm.
- b) Create the GuessingGame application. The application output should look similar to:
- ```
Enter a number between 1 and 20: 14
Computer's Number: 20
Player's Number: 14
Better luck next time.
```
- c) Write down how the application was tested and list any debugging techniques used.

## Exercise 10

## Volumes

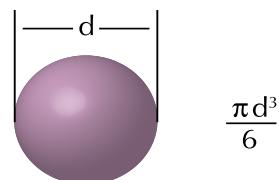
The volume of objects are calculated differently depending on the shape of the object.

- a) The volume of rectangular prism is calculated using the formula:



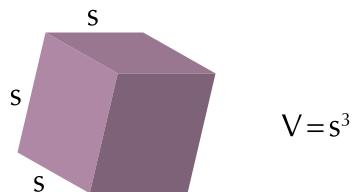
Create a Volumes application that prompts the user for the length, width, and height of a rectangular prism and then calculates the volume.

- b) The volume of a sphere is calculated using the formula:



Modify the Volumes application to prompt the user for the radius ( $d = 2 \cdot r$ ) of a sphere after displaying the volume of the rectangular prism. The application should then display the volume of the sphere.

- c) The volume of a cube is calculated using the formula:



Modify the Volumes application to prompt the user for the length of each side of a cube after displaying the volume of the rectangular prism and the sphere. The application should then display the volume of the cube.

The application output should look similar to:

```
Rectangular Prism
Enter the length: 3
Enter the width: 4
Enter the height: 5
The volume is: 60.00

Sphere
Enter the radius: 3
The volume is: 113.10

Cube
Enter the length of each side: 4
The volume is: 64.00
```

## Exercise 11

## QuadraticEquation

Create a QuadraticEquation application that gives the solution to any quadratic equation. The application should prompt the user for values for a, b, and c ( $ax^2 + bx + c = 0$ ) and then display the roots, if any. The quadratic equation takes the form:

$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Application output should look similar to:

```
Enter value for a: 2
Enter value for b: 4
Enter value for c: -30
The roots are 3.0 and -5.0
```

## Exercise 12

## MyPow

Create a MyPow application that uses the formula  $e^{(Y * \log(X))}$  to calculate  $X^Y$ . The MyPow application should prompt the user for two numbers and then display the result from the formula and, for comparison, show the same result using the Math pow() method. The application should display output similar to:

```
Enter a value for X: 7
Enter a value for Y: 5

The result from using the formula is: 16806.9999999998
The result from using the Math pow() method is: 16807.0
```

The Math library provides methods for calculating base 10 and base  $e$  (natural) logarithms. The exp() method raises  $e$  to a given power:

Class Math (java.lang.Math)

### Methods

|                   |                                         |
|-------------------|-----------------------------------------|
| log(double num)   | returns the natural logarithm of num.   |
| log10(double num) | returns the base 10 logarithm of num.   |
| exp(double num)   | returns $e$ raised to the power of num. |

## Exercise 13

## CarPayment

Create a CarPayment application that calculates a monthly car payment after prompting the user for the principal owing (P), the interest rate (r) and the number of monthly payments (m). The monthly car payment is calculated using the formula:

$$\frac{P(r/12)}{(1 - (1 + r/12)^{-m})}$$

Application output should be similar to:

```
Principal: 20000
Interest Rate: .07
Number of monthly payments: 48
The monthly payment is $478.92
```

## Exercise 14

## BacteriaGrowth

The formula  $y = ne^{kt}$  can be used for estimating growth where:

- y is the final amount
- n is the initial amount
- k is a constant
- t is the time

For example, this formula could be used for estimating population growth in a region or for estimating cell growth in a lab experiment. Create a BacteriaGrowth application that calculates how many bacteria will be present based on this formula. The application should prompt the user initial bacteria, the constant k, and the time. Refer to Exercise 12 for documentation for the Math methods for this exercise. Application output should look similar to:

```
Enter initial bacteria amount: 5
Enter a constant value for k: .8
Enter the growth time period in hours: 8
3009.2 bacteria will be present after 8.0 hours.
```

## Exercise 15

## Decay

The formula used in Exercise 14 for growth problems can also be used in decay problems. In decay problems, k is negative. Create an application that allows the user to select from the following options:

- calculate the final amount:  $ne^{-kt}$
- calculate the initial amount:  $y / e^{-kt}$
- calculate the constant (called the half-life):  $(\log(y/n)) / t$   
(where  $\log e = 0.4343$ )

The application should prompt the user to select one of the three choices and based on the selected option prompts the user to enter the appropriate known information. For example, a radioactive mass of 200 grams will reduce to 100 grams in 10 years. Based on this information, the half-life is calculated to be -0.06931. Refer to Exercise 12 for documentation for the Math methods for this exercise. Application output should look similar to:

```
1. Final Amount
2. Initial Amount
3. Constant <half-life>
Find:3
Enter initial mass: 200
Enter final mass: 100
Enter elapsed time in years: 10
Constant <half-life>: -0.06931
```

## Exercise 16

## TrigFunctions

Create a TrigFunctions application that prompts the user for an angle in degrees and then displays the sine, cosine, and tangent of the angle. The application should display output similar to:

```
Enter an angle in degrees: 30
Sine: 0.5
Cosine: 0.87
Tangent: 0.58
```

The Math library provides methods for performing trigonometric functions:

Class Math (java.lang.Math)

Methods

|                                    |                                                                                    |
|------------------------------------|------------------------------------------------------------------------------------|
| <code>sin(double angle)</code>     | returns the sine of <code>angle</code> , where <code>angle</code> is in radians.   |
| <code>cos(double angle)</code>     | returns the cosine of <code>angle</code> , where <code>angle</code> is in radians. |
| <code>tan(double angle)</code>     | returns the sine of <code>angle</code> , where <code>angle</code> is in radians.   |
| <code>toRadians(double deg)</code> | converts degrees to radians.                                                       |

## Exercise 17

## InverseTrigFunctions

Create an InverseTrigFunctions application that prompts the user for an angle in degrees and then displays the arcsin, arccos, and arctan of the angle. The application should display output similar to:

```
Enter an angle in degrees: 30
Arcsin: 0.55
Arccos: 1.02
Arctan: 0.48
```

The Math library provides methods for performing trigonometric functions:

Class Math (java.lang.Math)

Methods

|                                    |                                                                      |
|------------------------------------|----------------------------------------------------------------------|
| <code>asin(double s)</code>        | returns the angle, in radians, that has the sine <code>s</code> .    |
| <code>acos(double s)</code>        | returns the angle, in radians, that has the cosine <code>s</code> .  |
| <code>atan(double s)</code>        | returns the angle, in radians, that has the tangent <code>s</code> . |
| <code>toDegrees(double rad)</code> | converts radians to degrees.                                         |

# Chapter 6

## Loop Structures and Strings

**L**oop structures, counters and accumulators, and flags are explained in this chapter. Debugging techniques and the String class are also discussed.

### The while Statement

#### *loop structure*

The `while` statement is a *loop structure*, which executes a set of statements over and over again based on a condition. Loop structures are used to perform tasks such as summing a set of numbers as they are entered by the user or repeatedly prompting the user for a value until valid data is entered. The `while` statement takes the form:

```
while (<condition>) {
 <statements>
}
```

The condition of the `while` loop is a Boolean expression, which is evaluated before the statements are executed. When the condition is true the statements are executed, when the condition is false program flow continues to the next statement after the closing curly brace of the `while`. Each execution of the loop is called an *iteration*. Note that a `while` loop may never execute if the condition initially evaluates to false.

#### *iteration*

#### **Nested Loops**

A loop structure can contain another loop structure. Loops placed within a loop are called *nested loops*. Each time the outer loop iterates, the inner loop iterates until its condition is met.

The following `while` statement executes five times:

```
int num = 0;
while (num < 5) {
 num += 1;
}
```

After the fifth execution, `num` is equal to 5, making the condition `false`.

### The do-while Statement

The `do-while` statement is an alternative form of the `while` statement. In the `do-while` statement the condition is not evaluated until after the first execution of the loop. Therefore, the `do-while` executes at least once.

The `do-while` takes the following form:

```
do {
 <statements>
} while (<condition>);
```

The following `do-while` example prompts the user until a valid number is entered:

```
do {
 System.out.print("Enter a number less than 4:");
 playerNum = input.nextInt();
} while (playerNum >= 4);
```

## Infinite Loops

The condition of a loop is used to determine when the loop should stop executing. A `while` continues until its condition is false. What happens, though, if the condition never becomes false? The result is an *infinite loop*—one which continues forever. For example, the following generates an infinite loop. Can you see why?

```
int num = -1;
while (num < 0) {
 num = -1;
}
```

The code causes the application to simply stop responding or just “hang.” When this happens, close the output window to end the application. Note that some compilers may require a different procedure to end an infinite loop.

Syntax errors are a common cause of infinite loops. For example, a semicolon after the condition causes the statement to check the condition, do nothing, check the condition, do nothing, and on and on:

```
while (num < 0); { //an infinite loop here--added semicolon
 num += 1;
}
```

Another example of a syntax error that can lead to an infinite loop is omitting the curly braces:

```
while (num < 0) //an infinite loop here--no braces
 System.out.print("Enter a value: ");
 num = input.nextInt();
```

In this case, only the first statement is executed and `num` is never assigned the input. Although properly done, the indentation makes it difficult to find the syntax error.

A logic error can also lead to an infinite loop condition. For example, in the code below `num` is initialized to 1 and never decremented to a number less than 0 in the loop, making the condition of the loop structure always true:

```
int num = 1;
do {
 num += 1;
} while (num >= 0);
```

In this case, the loop isn’t infinite because `num` is eventually assigned a **overflow** number so large that an overflow results. An *overflow* occurs when there are not enough bits to store a number. This may generate a run-time error or, in the case of the code above, actually cause the condition to become false. An overflow changes the sign of the number stored.

## Review: Promter

Create a Promter application that prompts the user for two numbers. The first number is a min value and the second is a max value. Promter then prompts the user for a number between the min and max numbers entered. The user should be continually prompted until a number within the range is entered. Be sure to include the min and max numbers in the prompt.

## Counters and Accumulators

Many algorithms require counting and summing values. For example, an application that calculates the average of a set of numbers must sum the numbers and then divide the total by the count. The AverageValue application performs counting and summing. A run of the application looks similar to:

```
Enter a value (0 to quit): 25
Enter a value (0 to quit): 14
Enter a value (0 to quit): 18
Enter a value (0 to quit): 22
Enter a value (0 to quit): 30
Enter a value (0 to quit): 0
Average is 21.8
```

The AverageValue application is based on the pseudocode:

```
Prompt user for a value
while (value != 0)
 count value
 add value to sum of values
 prompt user for another value
Display average of values (sum/count)
```

A program that counts the number of values entered by the user is actually counting the number of loop iterations. To count loop iterations, a statement similar to the following is used within the loop:

```
numValues += 1;
```

Each time the statement executes, one is added to the current value of the variable. This type of variable is called a *counter* because it is incremented by a constant value. Counters are useful for keeping track of the number of times a user enters a value, makes a guess, or types a password. A counter should be initialized when it is declared and then incremented by a fixed amount.

A similar assignment statement is used to sum values as they are entered by the user:

```
sumOfValues += newValue;
```

Each time the statement executes, the value of `newValue` is added to the current value of the variable. This type of variable is called an *accumulator* because its value “accumulates.” As with a counter, an accumulator should be initialized when it is declared.

The AverageValue code includes both a counter (`numValues`) and an accumulator (`sumOfValues`):

```
/* AverageValue application. */

import java.util.Scanner;

/**
 * Displays the average of a set of numbers
 */
public class AverageValue {

 public static void main(String[] args) {
 final int SENTINEL = 0;
 int newValue;
 int numValues = 0;
 int sumOfValues = 0;
 double avg;
 Scanner input = new Scanner(System.in);

 /* Get a set of numbers from user */
 System.out.println("Calculate Average Program");
 System.out.print("Enter a value (" + SENTINEL + " to quit): ");
 newValue = input.nextInt();
 while (newValue != SENTINEL) {
 numValues += 1;
 sumOfValues += newValue;
 System.out.print("Enter a value(" + SENTINEL + " to quit): ");
 newValue = input.nextInt();
 }
 input.close();

 /*Calculate average of numbers entered by user */
 avg = (double)sumOfValues / (double)numValues;
 System.out.println("Average is " + avg);
 }
}
```

The AverageValue code uses a constant named `SENTINEL`. This constant stores a value to act as a *flag*, or *sentinel*, to signify that the loop should stop iterating. AverageValue defines the sentinel with a constant. Another approach is to use a variable and prompt the user for the sentinel value.

## Review: Evens

Create an Evens application that displays the even numbers between 1 and 20, inclusive.

## Review: NumbersSum

Create a NumbersSum application that prompts the user for a number and then displays the numbers 1 through the number entered, each on a separate line. Below the numbers, the sum is displayed.

## Review: PercentPassing

Create a PercentPassing application that prompts the user for a set of scores and then calculates the percentage of scores above 70%. The user should have the option to enter as many scores as needed. (Hint: Use an `if` statement and another counter.)

# The for Statement

The `for` statement is a loop structure that executes a set of statements a fixed number of times. The `for` statement takes the form:

```
for (<initialization>; <condition>; <increment>) {
 <statements>
}
```

The initialization is performed only once when a `for` statement is executed. The condition is a Boolean expression, which is evaluated before each loop iteration. When the condition is true the statements are executed, when false, program flow continues to the next statement after the closing curly brace of the `for`. After each loop iteration, the increment is executed.

## loop control variable

**TIP** Counter variables in a `for` loop are often named `i`, `j`, or `k`.

## scope

## programming style

## increment operator

### Expressions Using ++ or --

If the `++` or `--` operator appears before the operand, it is called *prefix* (i.e. `++i`). An operator after the operand is called *postfix* (i.e. `i++`). Either operator location has the same effect on the final value of the operand. However, in an expression, the prefix version uses the value of the operand *after* the operation. For example, when `x` is 12, the statement `++x` returns 13. In the postfix version, `x++`, 12 is returned. Therefore, a statement such as `x++ >= 13` is false and could be ambiguous. Using the `++` and `--` operators in an expression is poor programming style.

Note that the counter is declared in the initialization of the `for` statement (`int i = 1`). With a declaration in this location, the *scope* of the counter is from the initialization to the closing curly brace of the `for` statement. The application will not recognize the variable outside of that statement. Declaring variables so that their scope is limited to where they are needed is good programming style because it produces cleaner code and helps eliminate the possibility of errors.

The statement above uses the `++` operator in the increment part of the `for` statement (`i++`). The `++` operator is called the *increment operator* because it increases the value of a variable by 1. The `++` operator is a good choice in the increment of a `for` statement because the effect is to increase the operand by 1. However, `++` should not be used within an expression, such as `i++ <= 10`, because the value returned by the operator is used in the expression, not the final value of the operand.

Any combination of components can be left out of a `for` statement. This can be useful when a counter is declared and initialized outside the statement, as in the following code:

```
int num;
System.out.print("Enter the starting number: ");
num = input.nextInt();
for (; num <= 10; num++) {
 System.out.println(num);
}
```

A `for` statement may also count down from a start value to an end value using the *decrement operator*, `--`:

```
for (int countDown = 10; countDown >= 0; countDown--) {
 System.out.println(countDown);
}
```

While it is possible to modify a loop control variable from within a `for` loop or to terminate a loop prematurely, this is considered poor programming style. Good programming style dictates that changes to the loop control variable occur in the increment portion of the loop only and that the loop end only when the condition is false.

## Review: Factorial

Create a Factorial application that prompts the user for a number and then displays its factorial. The factorial of a number is the product of all the positive integers from 1 to the number. For example,  $5! = 5*4*3*2*1$ .

## Review: OddSum

Create an OddSum application that prompts the user for a number and then sums the odd numbers from 1 to the number entered.

## Debugging Techniques

**TIP** A “bug” is an error in a program.

The source of bugs, which are often logic errors, can be hard to determine without tools for debugging an application. *Debugging* is the process of getting an application to work correctly. One tool included with many compilers is called a debugger.

### debugger breakpoints

A *debugger* is used to select statements where execution will be suspended. These statements are called *breakpoints*. Application output goes to a Debug Window and statements can be executed one at a time between breakpoints by using a Step command. When stepping through an application, selected variables are displayed in a Watch window along with their value. When a watch variable is assigned a new value, the Watch window is updated. Stepping through code and watching variables can an effective way to determine logic errors.

### variable trace

Another debugging tool is called a variable trace and is done manually. A *variable trace* is a table listing the values of variables at the points of assignment. For the following code, `num1` and `num2` would be included in a variable trace:

```
int num1 = 0;
int num2 = 0;
while (num1 < 10) {
 if (num1 % 3 == 0) {
 num2 += num1;
 System.out.print(num2 + " ");
 }
 num1 += 1;
}
```

**TIP** A common error with loops is an off-by-one error. This occurs when a loop iterates one too many or one too few times due to a Boolean expression error.

The variables are listed in the order that assignment occurs within the loop. Output is also listed to better understand the code:

| num2 | output | num1 |
|------|--------|------|
| 0    | 0      | 1    |
|      |        | 2    |
|      |        | 3    |
| 3    | 3      | 4    |
|      |        | 5    |
|      |        | 6    |
| 6    | 6      | 7    |
|      |        | 8    |
|      |        | 9    |
| 9    | 9      | 10   |

### *additional println()*

A third debugging technique involves adding additional `println()` statements to an application. Adding `println()` statements just after a variable is assigned a new value or before and after a condition is evaluated can help detect the source of a logic error. For example, the code segment below includes additional statements for debugging:

```
int num1 = 0;
int num2 = 0;
System.out.println("num1 before while: " + num1); //debug
while (num1 < 10) {
 System.out.println("num1 in while: " + num1); //debug
 if (num1 % 3 == 0) {
 num2 += num1;
 System.out.println("num2: " + num2); //debug
 System.out.println(num2 + " ");
 }
 num1 += 1;
}
```

When run, the code above displays the following output, which can be compared to the values expected. Note the similarity to a variable trace:

```
num1 before while: 0
num1 in while: 0
num2:0
0
num1 in while: 1
num1 in while: 2
num1 in while: 3
num2:3
3
num1 in while: 4
num1 in while: 5
num1 in while: 6
num2:9
9
num1 in while: 7
num1 in while: 8
num1 in while: 9
num2:18
18
```

### *commenting out code*

Commenting out statements can be an effective way to locate a bug through process of elimination. Typically the `//` characters are easiest to type at the beginning of a statement to “comment it out.”

## Review: Variable Trace

Using paper and pencil, create a variable trace for the following code, tracing the values of `num1`, `num2`, `i`, and any output:

```
int num1 = 0;
int num2 = 0;
for (int i = 0; i <= 4; i++) {
 num1 = i * i;
 num2 += num1;
 System.out.print(num1 + " ");
}
System.out.println(num2);
```

# The String Class

Primitive data types such as `int` and `double` are used for storing numeric data. However, when data is comprised of a sequence of characters, a data type for storing strings is needed. Java includes the `String` class in the `java.lang` package for storing and manipulating strings. The `String` class is large, with numerous methods for string manipulation. Some of the `String` class methods include:

## More on Concatenation

As introduced in Chapter 4, concatenation appends one string to another. When the `+` operator is used to join a string and a numeric, the compiler first converts any non-`String` data to a `String` object before joining the strings. The `String` class also contains the `concat()` method for joining two strings.

## index

The position of a character in a string is called its *index*. The first character of a string is at index 0. The last character of a string is at index `length() - 1`. The `MiddleThree` class below displays the three letters in the middle of a string:

```
public class MiddleThree {
 public static void main(String[] args) {
 String phrase, threeLetters;
 int phraseLength;
 int mid;
 Scanner input = new Scanner(System.in);

 /* get string from user */
 System.out.print("Enter text that contains at least
 three characters: ");
 phrase = input.nextLine();
 input.close();

 /* determine middle of phrase */
 phraseLength = phrase.length();
 mid = phraseLength / 2;
```

```

 /* display middle three characters */
 threeLetters = phrase.substring(mid - 1, mid + 2);
 System.out.println("Middle three characters are: "
 + threeLetters);
 }
}

```

Note that the String objects (`phrase`, `threeLetters`) can be declared in the same way primitives are declared—the data type followed by the variable name. With the String class, the following two statements perform the same task:

```

String alpha = new String("abc"); //these assignments are
String alpha = "abc"; //effectively the same

```

The MiddleThree application produces output similar to:

```

Enter text (at least three characters): abcde
Middle three characters are: bcd

```

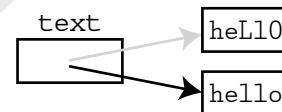
### immutable

A string is said to be *immutable* because it cannot be changed. Methods that manipulate the original string, for example `toLowerCase()`, create a new string in memory because the original string cannot be changed. Assigning a new string to a String object simply changes the object reference to point to the new string in memory. For example, the following code generates a new string. Assigning the string to the `text` object changes the object's reference:

```

String text;
text = "heLl0";
text = text.toLowerCase();
System.out.println(text);

```



The code produces the output:

```

hello

```

### null NullPointerException

Until a String object is assigned a value, it refers to `null`. Calling a method from a null String object generates the exception `NullPointerException`.

## Review: AccountSetup

Create an `AccountSetup` application that prompts the user for a user name and a password. The application should prompt the user until a password with at least eight characters is entered. The user name and password should be converted to all lowercase letters and then an appropriate message displayed. Application output should look similar to:

```

Enter a user name: WHIZKID
Enter a password that is at least 8 characters: Guess
Enter a password that is at least 8 characters: Programmer
Your user name is whizkid and your password is programmer

```

# Comparing Strings

Strings are compared when determining equality or alphabetical order. In chapter 5, relational operators, including == and >, were used to compare primitive types. When objects need to be compared, methods from their class are used. Some of the String class methods for comparing strings include:

## Class String (java.lang.String)

### Methods

`equals(String str)`

returns true when the string is the same as str.  
Returns false otherwise.

`equalsIgnoreCase(String str)`

same as equals() except that uppercase and lowercase differences between the strings are ignored.

`compareTo(String str)`

returns 0 when str is the same as the string, a negative integer is returned when str comes alphabetically after the string, and a positive integer is returned when str comes alphabetically before the string. Note that uppercase and lowercase letters are considered different.

`compareToIgnoreCase(String str)`

same as compareTo() except that uppercase and lowercase differences between the strings are ignored.

`indexOf(String str)`

returns the integer corresponding to the location of the first occurrence of str in the string. Otherwise -1 is returned.

`lastIndexOf(String str)`

returns the integer corresponding to the location of the last occurrence of str in the string. Otherwise -1 is returned.

`startsWith(String str)`

returns true when the string begins with str.  
Returns false otherwise.

`endsWith(String str)`

returns true when the string ends with str.  
Returns false otherwise.

The AlphaOrder class compares two strings and then displays them in alphabetical order:

```
public class AlphaOrder {

 public static void main(String[] args) {
 String word1, word2;
 Scanner input = new Scanner (System.in);
```

```

 System.out.print("Enter a word: ");
 word1 = input.nextLine();
 System.out.print("Enter a second word: ");
 word2 = input.nextLine();
 input.close();

 if (word1.compareToIgnoreCase(word2) == 0) {
 System.out.println("Words are equal.");
 } else if (word1.compareToIgnoreCase(word2) < 0) {
 System.out.println("In alphabetical order: " + word1
 + " " + word2);
 } else {
 System.out.println("In alphabetical order: " + word2
 + " " + word1);
 }
 }
}

```

AlphaOrder produces output similar to the following:

```

Enter a word: bear
Enter a second word: alligator
In alphabetical order: alligator bear

```

## Review: FormalGreeting

Create a FormalGreeting application that prompts the user for his or her name, including title. The application should display “Hello, sir.” if the string starts with Mr., “Hello, ma’am.” if the string starts with Ms., Mrs., or Miss, and “Hello, *name*.” otherwise where *name* is the user’s name.

## Chapter 6 Case Study

In this case study, a word guessing game will be created. The word guessing game allows the player to guess the letters of a secret word. At the start of the game, the player is shown only how many letters the word contains through a set of dashes. When a letter matching one in the word is guessed, it replaces the appropriate dash. Play continues until the entire word is guessed letter-by-letter or when the player chooses to guess the entire word.

### WordGuess Specification

WordGuess is played between the computer and a single player. The secret word is BRAIN. At the start of the game, six dashes are displayed (-----), one for each letter of the word. The player is repeatedly prompted for a letter guess. When a letter matching one in the word is guessed, the letter replaces the corresponding dash. Letters may be entered as uppercase or lowercase. However, only uppercase letters should be displayed. If the player enters an exclamation point (!), the player is prompted to guess the word. At that point the player either wins (a correct guess) or loses (an incorrect guess). Alternatively, the player can continue to guess letters until the entire word is revealed. The game ends by showing the player the total number of guesses.

The WordGuess interface should display a row of dashes, one dash for each letter in the word. Prompts should be used to get letter guesses from the player. As corresponding letters are guessed, the letter is displayed instead of the dash. At the end of the game, the user should be shown the word along with the number of guesses.

The WordGuess output sketch:

```
WordGuess game.

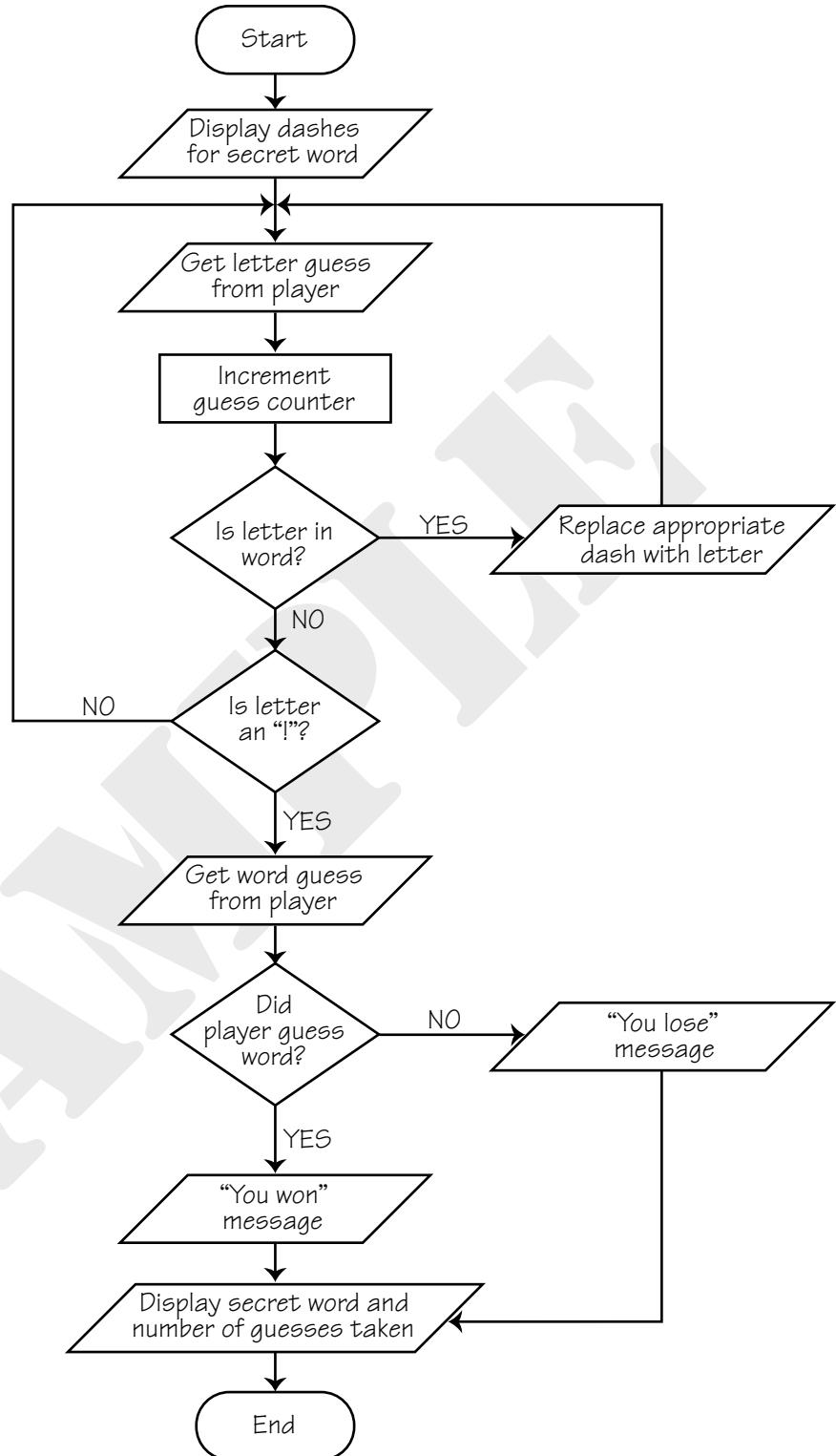
Enter a letter (! to guess entire word): a
--A--
Enter a letter (! to guess entire word): v
--A--
Enter a letter (! to guess entire word): !
--A--

What is your guess?
brain
You won!
The secret word is BRAIN
You made 3 guesses.
```

The WordGuess algorithm:

1. Display a row of dashes to represent the word.
2. Prompt the user for a letter guess.
3. If the letter guessed is part of the word, then display that letter in place of the corresponding dash.
4. Repeat steps 2 and 3 until all the letters have been guessed or an exclamation point has been entered by the user.
5. If an exclamation point has been entered, prompt the user to guess the entire word.
6. If the player correctly guesses the entire word or all the letters have been guessed, then display a message indicating that the player has won, otherwise the message should indicate that the player has lost.
7. Display the secret word and the number of guesses.

The WordGuess flowchart:



## WordGuess Code Design

The input for WordGuess are letters typed by the user. A String variable to store the player's letter guess will be needed. The player may also choose to guess the entire word, so another String variable to store a word guess will be needed.

The output for WordGuess is the secret word displayed as dashes and then redisplayed whenever a dash should be replaced by a letter, a prompt for the user's guess, a message indicating a win or loss, and a message indicating the secret word and the number of guesses made.

Data generated by WordGuess is a count of the number of guesses made by the user. A counter variable to store the number of guesses will be needed. Other data used in this application can be represented by String constants to represent the secret word (SECRET\_WORD) and to use as a loop sentinel (FLAG). A String variable will also be needed to "build" a new string that contains any correctly guessed letters.

Based on the algorithm and flowchart, the code design for the WordGuess application will include a loop structure to compare the user's input to the letters in the secret word. The best loop structure will be a `do-while` because under any condition the loop statements should iterate at least once. It is unknown how many times the loop statements should iterate, so a type of `while` statement, not a `for` statement, should be used. This comparison will be done with an `if` statement. A pseudocode algorithm for WordGuess follows:

```
Generate and display a set of dashes that represent the word
do
 update guesses counter
 Prompt user for a letter
 Convert to all uppercase
 Determine if letter is in word
 if letter is in word
 Create new string that contains the guessed letter
 while (all letters haven't been guessed and user hasn't chosen
 to guess the entire word)
 if (! has been entered)
 get a word guess from player
 convert word to all uppercase
 if (word guessed equals secret word OR all the letters have
 been guessed)
 display message that player has won
 else
 display message that player has lost
 Display secret word
 Display number of guesses
```

## WordGuess Implementation

Based on the code design, the WordGuess implementation follows:

```
/*
 * WordGuess.java
 */
import java.util.Scanner;
```

```

/**
 * Plays a word guessing game with one player.
 */
public class WordGuess {

 public static void main(String[] args) {
 final String SECRET_WORD = "BRAIN";
 final String FLAG = "!";
 String wordSoFar = "", updatedWord = "";
 String letterGuess, wordGuess = "";
 int numGuesses = 0;
 Scanner input = new Scanner(System.in);

 /* begin game */
 System.out.println("WordGuess game.\n");
 for (int i = 0; i < SECRET_WORD.length(); i++) {
 wordSoFar += "-"; //word as dashes
 }
 System.out.println(wordSoFar + "\n"); //display dashes

 /* allow player to make guesses */
 do {
 System.out.print("Enter a letter (" + FLAG + " to guess entire word): ");
 letterGuess = input.nextLine();
 letterGuess = letterGuess.toUpperCase();

 /* increment number of guesses */
 numGuesses += 1;

 /* player correctly guessed a letter--extract string in wordSoFar
 * up to the letter guessed and then append guessed letter to that
 * string Next, extract rest of wordSoFar and append after the guessed
 * letter
 */
 if (SECRET_WORD.indexOf(letterGuess) >= 0) {
 updatedWord = wordSoFar.substring(0, SECRET_WORD.indexOf(letterGuess));
 updatedWord += letterGuess;
 updatedWord += wordSoFar.substring(SECRET_WORD.indexOf(letterGuess)+1,
 wordSoFar.length());
 wordSoFar = updatedWord;
 }

 /* display guessed letter instead of dash */
 System.out.println(wordSoFar + "\n");
 } while (!letterGuess.equals(FLAG) && !wordSoFar.equals(SECRET_WORD));

 /* finish game and display message and number of guesses */
 if (letterGuess.equals(FLAG)) {
 System.out.println("What is your guess? ");
 wordGuess = input.nextLine();
 wordGuess = wordGuess.toUpperCase();
 }
 if (wordGuess.equals(SECRET_WORD) || wordSoFar.equals(SECRET_WORD)) {
 System.out.println("You won!");
 } else {
 System.out.println("Sorry. You lose.");
 }
 System.out.println("The secret word is " + SECRET_WORD);
 System.out.println("You made " + numGuesses + " guesses.");
 }
}

```

A run of WordGuess looks similar to:

WordGuess game.

-----

```
Enter a letter (! to guess entire word): a
--A--
```

```
Enter a letter (! to guess entire word): u
--A--
```

```
Enter a letter (! to guess entire word): b
B-A--
```

```
Enter a letter (! to guess entire word): n
B-A-N
```

```
Enter a letter (! to guess entire word): !
B-A-N
```

```
What is your guess?
brain
You won!
The secret word is BRAIN
You made 5 guesses.
```

### WordGuess Testing and Debugging

This case study should test all possible guess combinations. For example, the player may enter an exclamation point on the first guess. Testing should also include incorrect word guesses.

## Review: WordGuess

Modify the WordGuess Chapter 6 Case Study to display a score at the end of each game. The player should start with 100 points and have 10 points taken off for each guess. The score should be updated and displayed as the game is played. Display a player loses message if the score gets down to 0.

## Chapter Summary

This chapter introduced loop structures and the String class. The `while` statement and `do-while` statement are loop structures that iterate a set of statements repeatedly based on a condition. The difference between the loops is when the condition is evaluated. The `while` statement evaluates the condition before any iterations are performed. The `do-while` does not evaluate the condition until after the first iteration.

Some syntax errors and logic errors can lead to an infinite loop, which executes forever causing the application to just hang. A logic error can also cause an overflow, which occurs when there are not enough bits to store a number.

Counters are used for keeping track of loop iterations and are used in applications that keep track of the number of guesses or the number of values entered. An accumulator is increased by varying amounts. Accumulators are often used to sum values. Both counters and accumulators should be initialized when they are declared.

A flag, also called a sentinel, is used to signify that a loop should stop iterating. Flags are usually a constant that is declared in the application, but may also be determined by prompting the user for a value.

The `for` statement is another loop structure. This loop structure executes a set of statements a fixed number of times. A loop control variable is used to determine loop iterations and can be declared in the `for` statement itself. When a variable is declared in a statement, its scope is limited to the opening and closing curly braces of that statement. The increment operator (`++`) and decrement operator (`--`) are used to increase or decrease the value of a `for` loop control variable.

Debugging techniques include using a debugger, often included with a compiler, and a variable trace, which is a manual technique. Debuggers have the advantage of being able to display the actual value of a variable as it changes. Other techniques include adding `println` statements before and after variable assignment. Commenting out statements can also locate an error through process of elimination.

The `String` class is used to declare string variables. It contains numerous methods for determining the length of a string, converting a string to lowercase or uppercase characters, extracting substrings, and for comparing strings. A string is immutable, which means it cannot be changed from its original value. However, a `String` object can be assigned a new string in memory. The characters of a string have an index value, with the first character at index 0.

Code conventions introduced in this chapter are :

- The statements of an `while` statement should be indented.
- The statements of a `do-while` statement should be indented.
- The statements of a `for` statement should be indented.
- Declare variables so that their scope is limited to where they are needed.
- Changes to a loop control variable should occur in the increment portion of the loop only, and the loop should end only when the condition is false.

## Vocabulary

**Accumulator** A variable that is incremented by varying amounts.

**Breakpoint** A statement selected where execution will be suspended.

**Counter** A variable that is incremented by a fixed value.

**Debugger** A tool included with some compilers for debugging.

**Debugging** The process of getting an application to work correctly.

**Decrement operator** The -- operator, which decreases the value of a variable by 1.

**Flag** *see* Sentinel.

**Immutable** Unable to change.

**Increment operator** The ++ operator, which increases the value of a variable by 1.

**Index** The position of a character in a string.

**Infinite loop** A loop that continues forever.

**Iteration** The execution of a loop.

**Loop control variable** A counter that is used to control the number of `for` loop iterations.

**Loop structure** A statement that executes a set of statements repeatedly based on a condition.

**NullPointerException exception** An exception thrown when operations on a null String are attempted.

**Overflow** A condition that occurs when a number is too large to be stored in a specified number of bits.

**Sentinel** A constant that stores a value that is used to signify that a loop should stop iterating. Also called a flag.

**Scope** The set of statements that can access a declared variable.

**Variable trace** A table listing the values of variables at the points of assignment. Used for manually debugging an application.

## Java

`++` The increment operator.

`--` The decrement operator.

`do-while` A loop structure that executes a set of statements over and over again based on a condition, which is evaluated after an iteration.

`for` A loop structure that executes a set of statements a fixed number of times.

`while` A loop structure that executes a set of statements over and over again based on a condition, which is evaluated before any iterations.

**String** A `java.lang` class with methods for manipulating and comparing strings.

## Critical Thinking

1. What is the purpose of a loop structure?
2. Explain the difference between a `while` statement and a `do-while` statement.
3. An input validation loop is a loop that checks user input for valid data. If valid data is not entered, the loop iterates until valid data is entered. In which review of this chapter did you write code for an input validation loop?
4.
  - a) What is an infinite loop?
  - b) List two types of errors that can lead to an infinite loop.
  - c) What is meant by overflow?
5. How many times will the `do-while` loop execute?

```
int x = 0;
do {
 x = x + 2;
} while (x < 120);
```
6. What initial value of `x` would make the loop infinite?

```
do {
 x = x + 3;
} while (x < 120);
```
7. Compare and contrast counters and accumulators. List two uses for each.
8. Write a `for` statement that sums the integers from 3 to 10, inclusive.
9. List two factors that should be considered when determining which loop structure to choose.
10.
  - a) List two methods for debugging an application.
  - b) Which method listed in part (a) would be best for debugging an application that generates random numbers that are used for determining the condition of an `if` statement? Why?
11. Consider the following assignment:

```
String x = "my string. ";
```

Determine the value returned by each of the following methods:
  - a) `x.length()`
  - b) `x.substring(0, 3)`
12. Consider the following statements:

```
String x = "lots of words.";
String y = "Lots of Words.";
String z = "Two words. ";
```

Determine the value returned by each of the following methods:
  - a) `x.equals(y)`
  - b) `x.equalsIgnoreCase(y)`
  - c) `x.compareTo(z)`
  - d) `x.compareToIgnoreCase(y)`
  - e) `x.compareToIgnoreCase(z)`
  - f) `x.indexOf("or")`
  - g) `x.lastIndexOf("o")`
  - h) `z.startsWith("Tw")`
  - i) `x.endsWith("ds")`
13.
  - a) Write an algorithm to count the number of words in a sentence.
  - b) Write an algorithm to count the number of letters in a sentence.

### True/False

14. Determine if each of the following are true or false. If false, explain why.
  - a) A `while` statement iterates once before evaluating the condition.
  - b) A counter is incremented by a constant amount.
  - c) An accumulator signifies that a loop should stop iterating.
  - d) Sentinel values must always be the value `-1`.
  - e) A variable declared in a `for` statement can be used again anywhere in the program code.
  - f) String variables are primitive data types.
  - g) The first character of a string has index position 1.
  - h) Strings are compared using relational operators such as `>`.
  - i) The `String` class includes a method for determining the location of a substring within a string.

## Exercises

### Exercise 1

#### PrimeNumber

- a) A prime number is an integer greater than 1 that is evenly divisible by only 1 and itself. For example, 2, 3, 5, and 7 are prime numbers, but 4, 6, 8, and 9 are not. Create a PrimeNumber application that prompts the user for a number and then displays a message indicating whether the number is prime or not. Hint: The % operator can be used to determine if one number is evenly divisible by another.
- b) Modify the application to prompt the user for two numbers and then display the prime numbers between those numbers.

### Exercise 2

#### PrimeFactors

The Fundamental Theorem of Arithmetic states that every positive integer is the product of a set of prime numbers. This set is called the prime factors. For example, the prime factors for 140 are 2, 2, 5, and 7 ( $2 \cdot 2 \cdot 5 \cdot 7 = 140$ ). Create a PrimeFactors application that prompts the user for a positive integer and then displays that integer's prime factors. Use the following pseudocode when implementing the PrimeFactors code:

```
Initialize a counter to 2
while the counter is less than or equal to the number
 if the counter divides the number evenly
 display the counter
 divide the number by the counter to get a new number
 else increment counter by 1
```

### Exercise 3

#### Investment

Create an Investment application that calculates how many years it will take for a \$2,500 investment to be worth at least \$5,000 if compounded annually at 7.5%

### Exercise 4



#### CarRecall

Modify the CarRecall application created in Chapter 5 Exercise 4 to allow the user to input as many model numbers as needed. Use 0 as a sentinel to end user input. The application output should look similar to:

```
Enter the car's model number or 0 to quit: 221
Your car is defective. It must be repaired.
Enter the car's model number or 0 to quit: 123
Your car is not defective.
Enter the car's model number or 0 to quit: 780
Your car is defective. It must be repaired.
Enter the car's model number or 0 to quit: 0
```

## Exercise 5

## DigitsDisplay

Create a DigitsDisplay application that prompts the user for a non-negative integer and then displays each digit on a separate line. Application output should look similar to:

```
Enter a positive integer: 789
7
8
9
```

## Exercise 6

## DigitsSum

Create a DigitsSum application that prompts the user for a non-negative integer and then displays the sum of the digits. Application output should look similar to:

```
Enter a positive integer: 892
The sum of the digits is: 19
```

## Exercise 7

## CubesSum

- Create a CubesSum application that prompts the user for a non-negative integer and then displays the sum of the cubes of the digits. Application output should look similar to:

```
Enter a positive integer: 223
The sum of the cubes of the digits is: 43
```

- Modify the application to determine what integers of two, three, and four digits are equal to the sum of the cubes of their digits.

## Exercise 8



## GuessingGame

The GuessingGame application created in Chapter 5 Exercise 8 would be more fun if users could make as many guesses as necessary to guess the secret number. Modify the GuessingGame application as follows:

- Modify the algorithm to allow for as many guesses as needed.
- Modify the flowchart based on the algorithm modifications.
- Modify the GuessingGame code. Application output should look similar to:

```
Enter a number between 1 and 20: 2
Try again.
Enter a number between 1 and 20: 18
Try again.
Enter a number between 1 and 20: 19
You won!
```

- d) A binary search is a divide-and-conquer technique for efficiently searching a list of numbers that are sorted from lowest to highest. A strategy that incorporates the binary search technique can be used by the Guessing Game player when making guesses about the secret number:
1. Guess the number halfway between the lowest and highest numbers.
  2. If the number guessed matches the secret number, then the player wins.
  3. If the number guessed is too high, then take the number guessed minus one and make this the highest number and go back to Step 1.
  4. If the number guessed is too low, then take the number guessed plus one and make this the lowest number and go back to Step 1.

For example, assuming 15 is the random number generated in the Guessing Game application, the game would play out as follows when the player uses a divide-and-conquer technique:

| Current Low | Current High | Player Types                 | Message Displayed |
|-------------|--------------|------------------------------|-------------------|
| 1           | 50           | 26 (i.e., $(1+50)/2=25.5$ )  | Too high.         |
| 1           | 25           | 13 (i.e., $(1+25)/2=13$ )    | Too low.          |
| 14          | 25           | 20 (i.e., $(14+25)/2=19.5$ ) | Too high.         |
| 14          | 19           | 16 (i.e., $(14+19)/2=16.5$ ) | Too high.         |
| 14          | 15           | 14 (i.e., $(14+15)/2=14.5$ ) | Too low.          |
| 15          | 15           | 15 (i.e., $(15+15)/2=15$ )   | You guessed it!   |

In another program run, assuming the random number generated is 20, the game would play out as follows using the same divide-and-conquer technique:

| Current Low | Current High | Player Types                 | Message Displayed |
|-------------|--------------|------------------------------|-------------------|
| 1           | 50           | 26 (i.e., $(1+50)/2=25.5$ )  | Too high.         |
| 1           | 25           | 13 (i.e., $(1+25)/2=13$ )    | Too low.          |
| 14          | 25           | 20 (i.e., $(14+25)/2=19.5$ ) | You guessed it!   |

When this approach is taken, it has been proven that a player will not be required to make more than  $\log_2 n$  guesses, in this case  $\log_2 50$ , or at most 6 guesses. Try this technique yourself. Explain in your own words why this works. Would this strategy be possible if hints were not given after each guess?

## Exercise 9

## PowersTable

Create a PowersTable application that displays a table of powers similar to:

| x^1 | x^2 | x^3 | x^4  | x^5  |
|-----|-----|-----|------|------|
| 1   | 1   | 1   | 1    | 1    |
| 2   | 4   | 8   | 16   | 32   |
| 3   | 9   | 27  | 81   | 243  |
| 4   | 16  | 64  | 256  | 1024 |
| 5   | 25  | 125 | 625  | 3125 |
| 6   | 36  | 216 | 1296 | 7776 |

## Exercise 10

## GCD

Create a GCD application that prompts the user for two non-negative integers and then displays the greatest common divisor (GCD) of the two numbers. The GCD is the largest integer that divides into both numbers evenly. An algorithm for finding the GCD is called Euclid's Algorithm. Use the following pseudocode when implementing the GCD code:

```
while (num2 > 0) {
 temp = num1 % num2;
 num1 = num2;
 num2 = temp;
}
```

Application output should look similar to:

```
Enter a number: 32
Enter a second number: 40
The GCD is 8
```

## Exercise 11

## ElapsedTimeCalculator

What comes 13 hours after 4 o'clock? Create an ElaspsedTimeCalculator application that prompts the user for a starting hour, whether it is am or pm, and the number of elapsed hours. The application then displays the time after that many hours have passed. Application output should look similar to:

```
Enter the starting hour: 7
Enter am or pm: pm
Enter the number of elapsed hours: 10
The time is: 5:00 am
```

## Exercise 12

## Necklace

An interesting problem in number theory is sometimes called the “necklace problem.” This problem begins with two single-digit numbers. The next number is obtained by adding the first two numbers together and saving only the ones digit. This process is repeated until the “necklace” closes by returning to the original two numbers. For example, if the starting two numbers are 1 and 8, twelve steps are required to close the necklace: 1 8 9 7 6 3 9 2 1 3 4 7 1 8

Create a Necklace application that prompts the user for two single-digit integers and then displays the sequence and the number of steps taken. The application output should look similar to:

```
Enter the first starting number: 1
Enter the second starting number: 8
1 8 9 7 6 3 9 2 1 3 4 7 1 8
```

## Exercise 13

## Hailstone

An interesting (yet unsolved) question in mathematics is called “hailstone numbers.” This series is produced by taking an initial integer, and if the number is even, dividing it by 2. If the number is odd, multiply it by 3 and add 1. This process is then repeated. For example, an initial number of 10 produces:

10, 5, 16, 8, 4, 2, 1, 4, 2, 1 ...

An initial value of 23 produces:

23, 70, 35, 106, 53, 160, 80, 40, 20, 10, 5, 16, 8, 4, 2, 1, 4, 2, 1 ...

Note that both numbers eventually reach the 4, 2, 1, 4, 2, 1 ... cycle. Create two applications (Hailstone1 and Hailstone2) that answer the following questions for initial values of 1 to 200:

- Do all integers from 1 to 200 eventually reach this cycle?
- What is the maximum number of iterations to reach the cycle and which starting number produces this maximum?

## Exercise 14

## DiceRolls

Create a DiceRolls application that displays five rolls of two dice where each die is numbered from 1 to 6. The application should also show the total of each roll:

| Dice 1 | Dice 2 | Total |
|--------|--------|-------|
| 6      | 1      | 7     |
| 6      | 4      | 10    |
| 3      | 3      | 6     |
| 3      | 5      | 8     |
| 3      | 1      | 4     |

## Exercise 15

## Chaos

“Chaos theory” is a subfield of mathematics which relies heavily on the computer. A simple chaos experiment is:

Start with any real number  $x$  between 0 and 1. Generate a new number using the “logistic equation:”

$$x = 2*x(1 - x)$$

Display this new  $x$  and repeat the process 50 times.

- Create a Chaos application that prompts the user for a starting value and then performs this experiment. Make a prediction about what happens for different starting values.
- Modify the application so that the 2 in the logistic equation can be replaced with a value specified by the user in the range 2 to 4, but the starting value of  $x$  is always 0.5. Note any interesting behavior.

## Exercise 16

## RandomWalk

In the “random walk” problem, a person is placed at the center of a 7 meter long bridge. Each step the person moves 1 meter either forward or backward at random.

Create a RandomWalk application that determines how many steps the person will walk before taking a step off the bridge. Have the application average 50 trials, and display the average and the greatest number of steps. (Hint: Generate a random number between 0 and 1, with 0 meaning to go forward and 1 meaning to go backward.)

## Exercise 17

## Password

Create a Password application that stores a secret password of your choice. The Password application should prompt the user for the password and then display “Welcome” if the correct password is typed. If after three tries the correct password has not been entered, the message “Access denied.” should be displayed. Application output should look similar to:

```
Enter the password: homework
The password you typed is incorrect.
Enter the password: football
The password you typed is incorrect.
Enter the password: fish
The password you typed is incorrect.
Access denied.
```

## Exercise 18

## Monogram

Create a Monogram application that prompts the user for his or her first name, middle name, and last name and then displays a monogram with the first and middle initials in lowercase and the last initial in uppercase. Application output should look similar to:

```
Enter your first name: Alonso
Enter your middle initial: H
Enter your last name: Eloy

Your monogram is: aEh
```

## Exercise 19

## RemoveString

Create a RemoveString application that prompts the user for a sentence and a string. The application should then remove every occurrence of the string from the sentence. The application should look similar to:

```
Enter a sentence: I hope you have a really nice day.
Enter a string: really
I hope you have a nice day.
```

## Exercise 20

## CountVowels

Create a CountVowels application that prompts the user for a string and then displays a count of the number of vowels in the string. Application output should look similar to:

```
Enter text: Java Programming Assignment
The number of vowels in Java Programming Assignment is 8
```

## Exercise 21

## GroupAssignment

Create a GroupAssignment application that prompts the user for his or her name and then displays a group assignment. The group assignment depends on the first letter of the student's last name. Last names beginning with A through I are assigned to Group 1, J through S are assigned to Group 2, T through Z are assigned to Group 3. Application output should look similar to:

```
Enter your first name: Janus
Enter your last name: Smith
Janus Smith is assigned to Group 2
```

# Chapter 7

## Methods

**O**bject-oriented programs use classes with methods to perform tasks. A program often performs several tasks, each with its own level of complexity. To manage these tasks, they are broken down into methods. This chapter discusses top-down program development and writing and documenting methods.

### Program Development Using Methods

**TIP** Top-down development is also called top-down design or step-wise refinement.

#### *top-down development*

#### *procedural abstraction*

The solution to a task can be developed by breaking the task down into smaller subtasks. These subtasks can then be reduced to yet simpler tasks. This process can be continued until the original task is broken down into units that describe a specific goal. As the task is broken down into smaller subtasks and then further into units, more detail for achieving the specific goal is added. This problem-solving approach describes a software development process called *top-down development*.

In top-down development, the first level of subtasks translates into the main() method. Levels of tasks below main() are developed into a series of additional methods. Using methods to define tasks is called *procedural abstraction*. For example, consider the following program specification:

TempConverter allows the user to convert a temperature from either Fahrenheit to Celsius or Celsius to Fahrenheit.

The algorithm for this application breaks the program specification down into the first level of subtasks:

1. Determine the type of conversion to be done.
2. Convert the temperature using the appropriate formula.

Step 2 can then be broken down into another level of subtasks:

- 2a. Prompt the user for a Celsius temperature.  
Convert the temperature to Fahrenheit using the formula:  
 $F=9/5C + 32$ .  
Display the temperature.
- 2b. Prompt the user for a Fahrenheit temperature.  
Convert the temperature to Celsius using the formula:  
 $C=5/9(F - 32)$ .  
Display the temperature.

Top-down development and procedural abstraction were used to break the program specification down into levels of subtasks, as shown on the previous page. Outlining the levels of subtasks in pseudocode defines a main() method and two other methods:

```
main()
 Prompt the user for the conversion type.
 Execute the appropriate method to convert the temperature.

fahrenheitToCelsius()
 Prompt the user for a temperature in degrees Fahrenheit
 Convert the temperature to degrees Celsius
 Display the temperature

celsiusToFahrenheit()
 Prompt the user for a temperature in degrees Celsius
 Convert the temperature to degrees Fahrenheit
 Display the temperature
```

The TempConverter application implements the pseudocode above:

```
import java.util.Scanner;

public class TempConverter {

 public static void fahrenheitToCelsius() {
 double fTemp, cTemp;
 Scanner input = new Scanner(System.in);

 System.out.print("Enter a Fahrenheit temperature: ");
 fTemp = input.nextDouble();
 input.close();

 cTemp = (double)5/(double)9*(fTemp - 32);
 System.out.println("The Celsius temperature is " + cTemp);
 }

 public static void celsiusToFahrenheit() {
 double cTemp, fTemp;
 Scanner input = new Scanner(System.in);

 System.out.print("Enter a Celsius temperature: ");
 cTemp = input.nextDouble();
 input.close();

 fTemp = (double)9/(double)5*cTemp + 32;
 System.out.println("The Fahrenheit temperature is "
 + fTemp);
 }

 public static void main(String[] args) {
 int choice;
 Scanner input = new Scanner(System.in);

 /* Prompt user for type of conversion */
 System.out.println("1. Fahrenheit to Celsius conversion.");
 System.out.println("2. Celsius to Fahrenheit conversion.");
 System.out.print("Enter your choice: ");
 choice = input.nextInt();
 if (choice == 1) {
 fahrenheitToCelsius();
 } else {
 celsiusToFahrenheit();
 }
 input.close();
 }
}
```

**TIP** Methods must be part of a class.

### call

The TempConverter controlling class contains two methods as well as a main() method. The methods are executed when they are called. A method *call* consists of the method name followed by parentheses. The if statement in the main() method on the previous page contains two method calls, fahrenheitToCelsius() and celsiusToFahrenheit().

TempConverter produces output similar to:

```
1. Fahrenheit to Celsius conversion.
2. Celsius to Fahrenheit conversion.
Enter your choice: 1
Enter a Fahrenheit temperature: 32
The Celsius temperature is 0.0
```

In this run of the application, the user entered 1 and therefore the fahrenheitToCelsius() method was called.

## Writing Methods

### method declaration

### method body

A method consists of a declaration and a body. The *method declaration* includes access level, return type, name, and parameters, if any. The *method body* contains the statements that implement the method. A method takes the form:

```
<access_level> <return_type> <name>(<parameters>) {
 <statements>
}
```

For example, consider the fahrenheitToCelsius() method from the TempConverter application:

```
public static void fahrenheitToCelsius() {
 double fTemp, cTemp;
 Scanner input = new Scanner(System.in);

 System.out.print("Enter a Fahrenheit temperature: ");
 fTemp = input.nextDouble();
 input.close();

 cTemp = (double)5/(double)9*(fTemp - 32);
 System.out.println("The Celsius temperature is " + cTemp);
}
```

### access level

### access modifier

### visibility

### class method

### void

The method above is a class method with access level public, return type void, name fahrenheitToCelsius, and no parameters. The *access level* of a method determines if other classes can call the method. The keyword public is an *access modifier*. A public method can be called by any other method. The access level of a method can also be thought of as its *visibility*. Access levels are discussed further in Chapter 8.

The keyword static declares the method a class method. A *class method* can be called from the class itself. Methods that are not class methods must be called from an instantiated object of that class.

The return type void means that the method will not return a value, and parameters are specified when a method needs values to perform its task. The body of the method starts with the first opening brace ({) and ends with the closing brace (}).

## naming conventions

Method names should indicate an action. Verbs make good method names. A method name should also begin with a lowercase letter and then an uppercase letter should begin each word within the name. Method names may not contain spaces.

## local scope

Methods can also have their own set of variables, constants, and objects. Variable, constant, and object declarations in the body of a method have a scope that extends from the declaration to the end of the method body. These variables, constants, and objects are said to be *local* to the method because their scope is limited to that method. For example, the fahrenheitToCelsius() method contains local variables `fTemp` and `cTemp` and a local object named `input`.

## Review: TimeConverter

Create a TimeConverter application that allows the user to choose among converting hours to minutes, days to hours, minutes to hours, or hours to days. Use methods as appropriate.

## Method Parameters

**TIP** The terms “parameter” and “argument” are often used synonymously.

A method declaration can include *method parameters*, which accept values from the method call. The data passed to the method can then be used inside the method to perform its task. For example, the `drawBar()` method includes an `int` parameter named `length`:

```
public static void drawBar(int length) {

 for (int i = 0; i < length; i++) {
 System.out.print("*");
 }
 System.out.println();
}
```

*passing data  
argument*

Data is given, or *passed*, to a method by enclosing the data in parentheses in the method call. The value or variable passed to a method is called the *argument*. For example, the RightTriangle application makes six calls to `drawBar()`. Each call passes a different variable argument:

```
public class RightTriangle {

 public static void drawBar(int length) {

 for (int i = 1; i <= length; i++) {
 System.out.print("*");
 }
 System.out.println();
 }

 public static void main(String[] args) {

 /* draw a right triangle with base size 6 */
 for (int i = 1; i <= 6; i++) {
 drawBar(i);
 }
 }
}
```

**TIP** The term “formal parameter” is sometimes used to refer to a parameter in the method declaration, and the term “actual parameter” is used to refer to the argument being passed to the method.

The RightTriangle application produces the output:

```
*
**


```

#### pass by value

In Java, arguments are *passed by value*, which means that the data stored in an argument is passed. An argument that is a primitive data type gives the method a copy of its value. An argument that is an object gives the method a copy of its reference that points to methods for changing object data. Therefore, a method can change the data stored in an object because it has access to the object's methods, but it cannot change the data stored in a primitive variable because the method does not have access to the actual location of the primitive data.

#### multiple parameters

**TIP** Passing an argument of a type that is not expected by a method generates the exception `IllegalArgumentException`.

When a method declaration includes more than one parameter, the parameters are separated by commas. For example, a modified `drawBar()` has an `int` parameter for the length of the bar and a `String` parameter for the character to use to draw the bar:

```
public static void drawBar(int length, String mark) {

 for (int i = 1; i <= length; i++) {
 System.out.print(mark);
 }
 System.out.println();
}
```

A call to the modified `drawBar()` method includes two arguments separated by commas:

```
drawBar(6, "$");
```

This call produces the following output:

```
$$$$$$
```

The order of the arguments in a method call is important because the first argument corresponds to the first parameter in the method declaration, the second argument corresponds to the second parameter, and so on. Note that argument names do not necessarily match parameter names. Descriptive variable names should be used throughout a program without regard to matching parameter names in a method declaration.

## Review: SpanishNumbers

Create a `SpanishNumbers` application that displays numbers 1 through 10 in Spanish. A method with an `int` parameter should display the Spanish word for the number passed. A loop structure in the `main()` method should be used to call the method ten times. The Spanish word equivalents for numbers 1 through 10 are:

|   |        |    |       |
|---|--------|----|-------|
| 1 | uno    | 6  | seis  |
| 2 | dos    | 7  | siete |
| 3 | tres   | 8  | ocho  |
| 4 | cuatro | 9  | nueve |
| 5 | cinco  | 10 | diez  |

## Review: DisplayBox – part 1 of 2

Create a DisplayBox application that prompts the user for a height and width and then displays a box of that size. The DisplayBox application should include a method named `drawBox()` that has two parameters and makes calls to the `drawBar()` method.

### Method Overloading

The method declaration is used by the compiler to determine which method to execute. Therefore, method names do not have to be unique as long as the parameters are different for methods with the same name. *Method overloading* is when more than one method of the same name is included in a class. For example, the following application contains two `drawBar()` methods:

```
public class MethodOverloadingExample {

 public static void drawBar(int length) {

 for (int i = 1; i <= length; i++) {
 System.out.print("*");
 }
 System.out.println();
 }

 public static void drawBar(int length, String mark) {

 for (int i = 1; i <= length; i++) {
 System.out.print(mark);
 }
 System.out.println();
 }

 public static void main(String[] args) {

 drawBar(10);
 drawBar(5, "@");
 }
}
```

The MethodOverloading application produces the output:

```

@@@
```

Note that the first call in `main()` executes the `drawBar()` method containing only one parameter. The second call executes the `drawBar()` method that contains two parameters. The compiler uses the types, order, and number of parameters to determine which method to execute.

## Review: DisplayBox – part 2 of 2

Modify the DrawBox application to ask the user if a specific character should be used for the display. For example, the prompt could be “Do you want to enter a character to use to display the box? (enter y for yes):” If the user types `y`, then prompt the user for the character. Otherwise, the default character should be used. The modified application should contain overloaded `drawBox()` and `drawBar()` methods.

## The return Statement

A method can return a value. For example, the `cubeOf()` method returns the cube of its parameter:

**TIP** The return types of methods cannot be used to distinguish one method from another for overloading.

```
public static double cubeOf(double x) {
 double xCubed;

 xCubed = x * x * x;
 return(xCubed);
}
```

The `return` statement is used to send a value back to the calling statement. A `return` statement can return only one value.

A method that returns a value must include the return type in the method declaration. For example, the `cubeOf()` method declaration declares a return type `double`. Return types can be primitive types, such as `int`, `double`, and `boolean`, or abstract types, such as the `String` class. The return type `void` is used when there will be no return value. A method declared as `void` does not contain a `return` statement.

A method that returns a value is called from a statement that will make use of the returned value, such as an expression or an assignment statement. For example, the following application calls `cubeOf()` from an assignment statement:

```
public class CubeCalculator {

 public static double cubeOf(double x) {
 double xCubed;

 xCubed = x * x * x;
 return(xCubed);
 }

 public static void main(String[] args) {
 double num = 2.0;
 double cube;

 cube = cubeOf(num);
 System.out.println(cube);
 }
}
```

The `CubeCalculator` application produces the following output:

**8.0**

## Review: Exponentiation

Create an Exponentiation application that prompts the user for two numbers and then displays the first number raised to the power of the second number. The application should include a method named powerOf() that returns its first parameter raised to the power of its second parameter.

## Documenting Methods

Methods should be carefully commented so that a reader of the program understands what task the method is performing and what data, if any, will be returned by the method. Method documentation is in the form of documentation comments (`/** */`) that appear just above the method declaration. For example, the drawBar() method with documentation:

```
/*
 * Print a bar of asterisks across the screen.
 * pre: length > 0
 * post: Bar drawn of length characters, insertion
 * point moved to next line.
 */
public static void drawBar(int length) {

 for (int i = 0; i < length; i++) {
 System.out.print("*");
 }
 System.out.println();
}
```

The assumptions, or initial requirements, of a method are stated in the *precondition* section of the documentation, or *pre*. Note that the *pre* for drawBar() states that `length` must be greater than 0, but not that `length` must be an `int`. Information that the compiler will verify, such as data types, should not be stated in method documentation.

### postcondition

The *postcondition* section of the documentation, or *post*, states what must be true after the method has been executed. However, the *post* should not state how the method accomplished its task.

A method may not have a precondition, but every method must have a postcondition. For example, below is the cubeOf() method with documentation:

```
/*
 * Calculates the cube of a number.
 * pre: none
 * post: x cubed returned
 */
public static double cubeOf(double x) {
 double xCubed;

 xCubed = x * x * x;
 return(xCubed);
}
```

To summarize, the guidelines for writing pre and post conditions are:

- The precondition states what must be true at the beginning of a method for the method to work properly.
- The postcondition states what must be true after the method has executed if the method has worked properly.
- Preconditions and postconditions should not state facts that the compiler will verify. They should also not refer to variables or information outside the method.
- The postcondition should not state how the method accomplished its task.

## Review

Modify each of the Reviews in this chapter so that the methods are properly documented.

## Chapter 7 Case Study

This case study will focus on top-down development and procedural abstraction. Testing and debugging methods in isolation will also be demonstrated.

An application for generating a letter grade based on a numeric grade will be created. The GradeConverter application allows the user to enter a numeric grade and then a letter grade is displayed. The user may then choose to enter another grade or quit.

### GradeConverter Specification

The GradeConverter application prompts the user for a numeric grade in the range 0 to 100 or a -1 to end the application. When a valid numeric grade is entered, the corresponding letter grade is then displayed. Grades from 90 to 100 are an A, grades from 80 to 89 are a B, grades from 70 to 79 are a C, grades from 60 to 69 are a D, and grades below 60 are an F. After displaying the corresponding letter grade, the user is prompted to enter another letter grade or can choose to quit the application.

The GradeConverter interface should include a prompt asking for the numeric grade. The prompt should give the option of quitting the application. After displaying the letter grade, the user should be prompted to enter another numeric grade or quit the application.

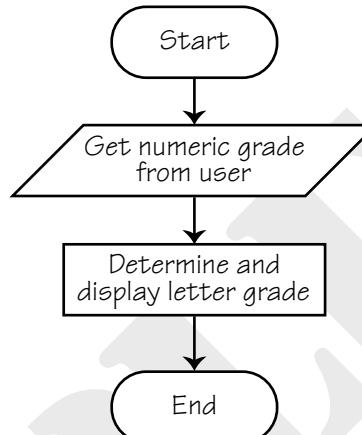
The GradeConverter output sketch:

```
Enter a numeric grade (-1 to quit): 88
The grade 88 is a(n) B.
Enter a numeric grade (-1 to quit): 90
The grade 90 is a(n) A.
Enter a numeric grade (-1 to quit): -1
```

The GradeConverter algorithm:

1. Prompt the user for a number.
2. Determine the letter grade that corresponds to the entered numeric grade and display the result.
3. Repeat steps 1 and 2 until the user chooses to quit.

The GradeConverter flowchart:



### GradeConverter Code Design

Using the top-down development approach, the algorithm is further refined:

Step 1 of the algorithm can be broken down further:

- 1a. Display a prompt that gives the user the option to quit.

Check that the number entered is valid. It should correspond to either a sentinel value that indicates the user wants to quit or a number in the range 0 through 100.

Step 2 of the algorithm can be broken down further:

- 2a. Determine if the numeric grade is between 90 to 100, 80 to 89, 70 to 79, 60 to 69, or 0 to 59.

Assign the letter A to a grade from 90 to 100, a letter B to a grade from 80 to 89, the letter C to a grade from 70 to 79, the letter D to a grade from 60 to 69, and the letter F to a grade from 0 to 59.

Using the flowchart, algorithm, and procedural abstraction, the pseudocode for the GradeConverter application can be created. The code will include a loop structure to get the user's input and two additional methods. One method will determine if the input is valid and another determines which letter corresponds to the numeric grade:

```
main()
Prompt the user for a number
while (number != -1) {
 if (isValidNumber(number)) {
 getLetterGrade(number)
 Display message with letter grade
 }
 Prompt the user for a number
}

isValidNumber(userNum, maxNum, minNum)
if (minNum <= userNum <= maxNum) {
 return (true);
} else {
 return (false);
}

getLetterGrade(numericGrade)
if (numericGrade < 60) {
 return ("F");
} else if (numericGrade < 70) {
 return ("D");
} else if (numericGrade < 80) {
 return ("C");
} else if (numericGrade < 90) {
 return ("B");
} else {
 return ("A");
}
```

### GradeConverter Implementation

Testing methods in isolation is important to ensure that the program as a whole will run without error. When testing a method, statements in main() should call the method using test data. The main() method should not call any other method or perform any other task except test the current method.

Rather than writing code for the entire application at once, one method at a time will be added and then tested. When testing the methods is complete, the main() method will be rewritten to implement the GradeConverter pseudocode.

The `isValidNumber()` method is the first method written and tested:

```
public class GradeConverter {

 /**
 * Determines if a numeric entry is valid.
 * pre: none
 * post: true return if minNum <= userNum <= maxNum;
 * false returned otherwise
 */
 public static boolean isValidNumber(int userNum, int minNum, int maxNum) {
 if (minNum <= userNum && userNum <= maxNum) {
 return(true);
 } else {
 return(false);
 }
 }

 public static void main(String[] args) {
 final int minValue = 0;
 final int maxValue = 100;
 int numericGrade;

 numericGrade = 0;
 if (isValidNumber(numericGrade, minValue, maxValue)) {
 System.out.println(numericGrade + " is valid.");
 } else {
 System.out.println(numericGrade + " is NOT valid.");
 }

 numericGrade = 100;
 if (isValidNumber(numericGrade, minValue, maxValue)) {
 System.out.println(numericGrade + " is valid.");
 } else {
 System.out.println(numericGrade + " is NOT valid.");
 }

 numericGrade = -1;
 if (isValidNumber(numericGrade, minValue, maxValue)) {
 System.out.println(numericGrade + " is valid.");
 } else {
 System.out.println(numericGrade + " is NOT valid.");
 }
 }
}
```

The statements in `main()` test the `isValidNumber()` method with data that includes boundary values. A *boundary value* is data that is just inside or just outside the range of valid values. For example, the value 100 lies just inside the high end of the range of valid grades. Testing the method with this data verifies that the `<=` operator was used rather than the `<` operator. The `GradeConverter` application produces the following output:

```
0 is valid.
100 is valid.
-1 is NOT valid.
101 is NOT valid.
```

Next, the getLetterGrade() method is added and the main() statements are changed to test that method:

```
public class GradeConverter {

 /**
 * Determines if a numeric entry is valid.
 * pre: none
 * post: true has been returned if minNum <= userNum <= maxNum;
 * false has been returned otherwise
 */
 public static boolean isValidNumber(int userNum, int minNum, int maxNum) {
 if (minNum <= userNum && userNum <= maxNum) {
 return(true);
 } else {
 return(false);
 }
 }

 /**
 * Determines the letter grade that corresponds to the numeric grade.
 * pre: 0 <= numGrade <= 100
 * post: The letter grade A, B, C, D, or F has been returned.
 */
 public static String getLetterGrade(int numGrade) {
 if (numGrade < 60) {
 return("F");
 } else if (numGrade < 70){
 return("D");
 } else if (numGrade < 80) {
 return("C");
 } else if (numGrade < 90) {
 return("B");
 } else {
 return("A");
 }
 }

 public static void main(String[] args) {
 int numericGrade;

 numericGrade = 90;
 System.out.println(numericGrade + " is " + getLetterGrade(numericGrade));
 numericGrade = 89;
 System.out.println(numericGrade + " is " + getLetterGrade(numericGrade));
 numericGrade = 80;
 System.out.println(numericGrade + " is " + getLetterGrade(numericGrade));
 numericGrade = 79;
 System.out.println(numericGrade + " is " + getLetterGrade(numericGrade));
 numericGrade = 70;
 System.out.println(numericGrade + " is " + getLetterGrade(numericGrade));
 numericGrade = 69;
 System.out.println(numericGrade + " is " + getLetterGrade(numericGrade));
 numericGrade = 60;
 System.out.println(numericGrade + " is " + getLetterGrade(numericGrade));
 numericGrade = 59;
 System.out.println(numericGrade + " is " + getLetterGrade(numericGrade));
 }
}
```

Boundary values for `getLetterGrade()` are tested with statements in `main()`. Running `GradeConverter` displays the output:

```
90 is A
89 is B
80 is B
79 is C
70 is C
69 is D
60 is D
59 is F
```

After verifying that the methods are working as expected, the final `GradeConverter` application can be completed:

```
/*
 * GradeConverter.java
 */

import java.util.Scanner;

/**
 * Display the letter grade that corresponds to the numeric
 * grade entered by the user.
 */
public class GradeConverter {

 /**
 * Determines if a numeric entry is valid.
 * pre: none
 * post: true has been returned if minNum <= userNum <= maxNum;
 * false has been returned otherwise
 */
 public static boolean isValidNumber(int userNum, int minNum, int maxNum) {
 if (minNum <= userNum && userNum <= maxNum) {
 return(true);
 } else {
 return(false);
 }
 }

 /**
 * Determines the letter grade that corresponds to the numeric grade.
 * pre: 0 <= numGrade <= 100
 * post: The letter grade A, B, C, D, or F has been returned.
 */
 public static String getLetterGrade(int numGrade) {
 if (numGrade < 60) {
 return("F");
 } else if (numGrade < 70){
 return("D");
 } else if (numGrade < 80) {
 return("C");
 } else if (numGrade < 90) {
 return("B");
 } else {
 return("A");
 }
 }
}
```

```

public static void main(String[] args) {
 final int FLAG = -1;
 final int minValue = 0;
 final int maxValue = 100;
 int numericGrade;
 String letterGrade;
 Scanner input = new Scanner(System.in);

 System.out.print("Enter a numeric grade (-1 to quit): ");
 numericGrade = input.nextInt();
 while (numericGrade != FLAG) {
 if (isValidNumber(numericGrade, minValue, maxValue)) {
 letterGrade = getLetterGrade(numericGrade);
 System.out.println("The grade " + numericGrade + " is a(n) " +
 letterGrade + ".");
 } else {
 System.out.println("Grade entered is not valid.");
 }
 System.out.print("Enter a numeric grade (-1 to quit): ");
 numericGrade = input.nextInt();
 }
}

```

The GradeConverter application produces output similar to:

```

Enter a numeric grade (-1 to quit): 88
The grade 88 is a(n) B.
Enter a numeric grade (-1 to quit): 90
The grade 90 is a(n) A.
Enter a numeric grade (-1 to quit): -1

```

### GradeConverter Testing and Debugging

Testing done at this point should test the logic in `main()` because the other methods have already been verified. The logic in `main()` is simple. Therefore, testing need only include verifying that the loop control variable is working as expected, the user is able to enter grades as expected, and that letter grades are returned for values entered by the user in the range 0 through 100.

## Review: GradeConverter

Modify the GradeConverter Case Study to display an A+ for a grade of 100, a B+ for a grade of 89, a C+ for a grade of 79, and a D+ for a grade of 69.

## Chapter Summary

This chapter introduced a new level of software development that included writing methods to perform tasks. In the software development process, top-down development is a problem-solving approach that breaks a task down into smaller subtasks and then further into units. Implementing these tasks with methods is called procedural abstraction.

Methods are executed in a statement by including the method name followed by parentheses. A statement that executes a method is said to call the method. When a method requires data to perform its tasks, the data is included inside the parentheses in the method call. A method that returns data must be called from an assignment statement or from inside an expression.

A method includes a declaration and a body. The method declaration includes the access level, return type, if any, method name, and parameters for receiving data, if necessary. The access level of a method can be declared `public`, which means that the method can be called from a statement in any other method. The keyword `public` is called an access modifier. A method declaration that includes the keyword `static` is a class method, which can be called from the class itself.

The return type of a method declares what type of value will be given back to the calling statement. The return type `void` indicates that the method will not return a value at all. Return types can be primitive types, such as `int` and `double`, or abstract data types, such as `String`. Methods that return a value must include a `return` statement in the method body.

A method can have multiple parameters. Arguments in a method call must be passed to a method in the same order as the parameter declarations. Methods with the same name, but with different parameters are said to be overloaded. The compiler determines which method to call by the types, order, and number of parameters in overloaded methods.

Primitive arguments are passed by value, which means that the data stored in the argument is passed, not a reference to the argument location. A method can only use the argument values in the task it performs. A method cannot change the data stored in an argument.

The body of a method can include variable, constant, and object declarations. These declarations are said to be local because they have a scope that extends just from the declaration to the end of the method body.

Careful documentation is important for the reader of a program to understand a method. Method documentation is enclosed by `/** */` and includes a brief description of the method, a precondition, and a postcondition. Every method must have a postcondition, but not every method requires a precondition.

Code conventions introduced in this chapter are:

- Method names should indicate an action and begin with a lower-case letter and then an uppercase letter should begin each word within the name.
- Method documentation should be enclosed in `/** */` comment blocks.
- Method documentation should include a brief description of the task the method performs, a precondition, and a postcondition.

## Vocabulary

**Access level** The part of a method declaration that determines if the method can be called by other classes.

**Access modifier** A keyword in the declaration of a method that determines the access level of a method.

**Argument** The value or variable passed to a method.

**Call** A statement that contains a method name followed by parentheses.

**Boundary value** A value that lies just inside or just outside the range of valid values.

**Class method** A method that can be called from the class itself.

**Local** Variables, constants, and objects that are declared within a method and therefore have a scope limited to that method.

**Method body** The statements that implement a method.

**Method declaration** The first line of a method, which contains the method name, access level, return type, and parameters, if any.

**Method overloading** Writing more than one method of the same name in a class.

**Method parameters** The part of a method declaration that accepts values from the method call.

**Pass** Giving data to a method by enclosing the data in parentheses in the method call.

**Pass by value** Passing the value of an argument to a method. The type of data passed depends on whether the argument is a primitive or an object.

**Precondition** The part of a method's documentation that states the assumptions, or initial requirements, of the method. Also called *pre*.

**Procedural abstraction** Breaking a task down into methods.

**Postcondition** The part of a method's documentation that states what must be true after the method has been executed. Also called *post*.

**Top-down development** A problem-solving approach where a task is broken down into subtasks and then the subtasks are reduced to yet simpler tasks.

**Visibility** The access level of a method.

## Java

`/** */` Used to enclose documentation comments for a method.

`public` An access modifier used in the declaration of a method to indicate that the method is visible to any other class.

`static` A keyword used in the declaration of a method to indicate that the method is a class method.

`void` A keyword used in the declaration of a method to indicate that the method will not return a value.

`return` Statement used to send a value from a method back to the calling statement.

# Critical Thinking

1. Use top-down development and procedural abstraction to write pseudocode for the following specification:  
The Pizza application allows the user to choose to display the instructions for making a pizza in either English or Spanish.
2. Explain the difference between method declaration and method body.
3. What type of keyword is used to change the access level of a method?
4. What is another word used for describing the access level of a method?
5. Explain the scope of each of the variables in the code below:

```
public class ScopeExample {
 public static void main(String[] args) {
 int var1;
 for (int var2 = 0; var2 < 5; var2++) {
 method1();
 }
 }

 public static void method1() {
 int var3;
 for (int var4 = 0; var4 < 2; var4++) {
 var3 += 1;
 }
 }
}
```
6. Write a method declaration for each of the following descriptions:
  - a) A class method named `getVowels` that can be called by any other method, requires a `String` parameter, and returns an integer value.
  - b) A class method named `extractDigit` that can be called by any other method, requires an integer parameter, and returns an integer value.
  - c) A class method named `insertString` that can be called by any other method, requires a `String` parameter and an integer parameter, and returns a `String` parameter.
7.
  - a) How does the compiler distinguish one method from another?
  - b) Can two methods in the same class have the same name? Explain.
8.
  - a) What is the `return` statement used for?
  - b) How many values can a `return` statement send back to the calling statement?
  - c) How is the declaration of a method returning a value different from the declaration of a method that does not return a value?
9. Find and explain the error in the code below:

```
public class MethodCallExample {

 public static void main(String[] args) {
 int num;
 doSomething();
 num = doSomething();
 }

 public static int doSomething() {
 return(5);
 }
}
```
10.
  - a) What type of comments should be used for describing a method?
  - b) What three things should the comments for a method describe?

## True/False

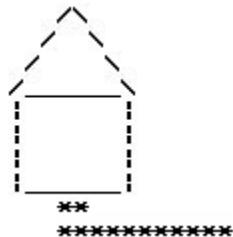
11. Determine if each of the following are true or false. If false, explain why.
  - a) Breaking a task down into methods is called procedural abstraction.
  - b) A method call consists of the method declaration in an assignment statement.
  - c) A void method must return a value.
  - d) An access modifier declares the return type of a method.
  - e) The keyword `static` declares a method is a class method.
  - f) Method parameters are enclosed by braces (`{}`).
  - g) Local variables can be used by any method in a class.
  - h) The value of an argument passed to a method can be changed in an assignment statement in the method.
  - i) Method overloading means that an application contains more than 10 methods.
  - j) The `return` statement is used to send a value back to the calling statement.
  - k) The precondition of a method states the data types of the method's parameters.
  - l) The postcondition of a method describes the way the method accomplishes its task.

## Exercises

### Exercise 1

### House

Create a House application that calls methods addRoof(), addBase(), and addWalk() to display the following:



### Exercise 2

### MetricConversion

The following formulas can be used to convert English units of measurements to metric units:

$$\text{inches} * 2.54 = \text{centimeters}$$

$$\text{feet} * 30 = \text{centimeters}$$

$$\text{yards} * 0.91 = \text{meters}$$

$$\text{miles} * 1.6 = \text{kilometers}$$

Create a MetricConversion application that displays a menu of conversion choices and then prompts the user to choose a conversion. Conversion choices should include inches to centimeters, feet to centimeters, yards to meters, miles to kilometers, and vice versa. The application should include separate methods for doing each of the conversions. Application output should look similar to:

```
Enter a number: 10
Convert:
1. Inches to Centimeters 5. Centimeters to Inches
2. Feet to Centimeters 6. Centimeters to Feet
3. Yards to Meters 7. Meters to Yards
4. Miles to Kilometers 8. Kilometers to Miles

Enter your choice: 1
10 inches equals 25.4 centimeters.
```

### Exercise 3

### PrimeNumber

Modify the PrimeNumber application created in Chapter 6 Exercise 1 to include a method named isPrime(). The isPrime() method should require one parameter and return a Boolean value.

## Exercise 4

## IsoTriangle

Create an IsoTriangle application that prompts the user for the size of an isosceles triangle and then displays the triangle with that many lines. The IsoTriangle application code should include:

- the drawBar() method from the chapter.
- An addSpaces() method which “prints” spaces.

Application output should look similar to:

```
Enter the size: 4
*


```

## Exercise 5

## AddCoins

Create an AddCoins application that prompts the user for the number of pennies, nickels, dimes, and quarters, and then displays their total dollar amount. The AddCoins application should include a getDollarAmount() method that has four int parameters corresponding to the number of pennies, nickels, dimes, and quarters, and returns a String that corresponds to the dollar value of the coins. Note that the String returned should include the currency sign (\$). Application output should look similar to:

```
Enter your total coins:
Quarters: 3
Dimes: 2
Nickels: 1
Pennies: 8
Total: $1.08
```

## Exercise 6

## PythagoreanTriple

Create a PythagoreanTriple application that displays all pythagorean triples with values of A and B less than 100. A pythagorean triple is a set of three integers that make the equation  $a^2 + b^2 = c^2$  true. The application should include a PerfectSquare() method that uses the solution from the PerfectSquare review in Chapter 6. (Hint: You will need to generate all possible combinations of A and B and display just those that work.)

## Exercise 7

## PerfectIntegers

Create a PerfectIntegers application that displays all perfect integers up to 100. A perfect integer is a number which is equal to the sum of all its factors except itself. For example, 6 is a perfect number because  $1 + 2 + 3 = 6$ . The application should include a boolean method `isPerfect()`.

## Exercise 8

## HiLo

- a) In the Hi-Lo game, the player begins with a score of 1000. The player is prompted for the number of points to risk and a second prompt asks the player to choose either High or Low. The player's choice of either High or Low is compared to random number between 1 and 13, inclusive. If the number is between 1 and 6 inclusive, then it is considered "low". A number between 8 and 13 inclusive is "high". The number 7 is neither high nor low, and the player loses the points at risk. If the player had guessed correctly, the points at risk are doubled and added to the total points. For a wrong choice, the player loses the points at risk. Create a HiLo application based on this specification. Application output should look similar to:

```
High Low Game
RULES
Numbers 1 through 6 are low
Numbers 8 through 13 are high
Number 7 is neither high or low

You have 1000 points.
Enter points to risk: 500
Predict (1=High, 0=Low): 0
Number is 4
You win.
Play again? y

You have 2000 points.
```

- b) Modify the application to allow the player to continue until there are 0 points left. At the end of the game, display the number of guesses the user took before running out of points.

## Exercise 9

### Nim

The game of Nim starts with a random number of stones between 15 and 30. Two players alternate turns and on each turn may take either 1, 2, or 3 stones from the pile. The player forced to take the last stone loses. Create a Nim application that allows the user to play against the computer. In this version of the game, the application generates the number of stones to begin with, the number of stones the computer takes, and the user goes first. The Nim application code should:

- prevent the user and the computer from taking an illegal number of stones. For example, neither should be allowed to take three stones when there are only 1 or 2 left.
- include an `isValidEntry()` method to check user input.
- include a `drawStones()` method that generates a random number from 1 to 3 for the number of stones the computer draws.
- include separate methods to handle the user's turn and the computer's turn.

Application output should look similar to that shown on the next page:

```
There are 22 stones. How many would you like? 3
There are 19 stones. The computer takes 2 stones.
There are 17 stones. How many would you like? 3
There are 14 stones. The computer takes 2 stones.
There are 12 stones. How many would you like? 3
There are 9 stones. The computer takes 3 stones.
There are 6 stones. How many would you like? 3
There are 3 stones. The computer takes 3 stones.
The player beats the computer!
```

## Exercise 10

### GuessingGame

The GuessingGame application modified in Chapter 6 Exercise 8 should include a separate method for displaying a hint to the user. Modify the GuessingGame application as follows:

- Modify the algorithm to include a call to a method named `giveHint()`, which displays a hint, but does not return a value.
- Modify the flowchart based on the algorithm modifications.
- Modify the GuessingGame code. Application output should look similar to:

```
Enter a number between 1 and 20: 15
Hint: try a higher number

Enter a number between 1 and 20: 17
Hint: try a lower number

Enter a number between 1 and 20: 16
You won!
```

# Chapter 8

## Classes and Object-Oriented Development

**J**ava applications use objects to perform tasks. Objects are defined with classes. This chapter explains how to design and write a class. The Object class and inheritance are introduced. Object-oriented development, encapsulation, and reusability are also discussed.

### What is an Object?

*state  
behavior*

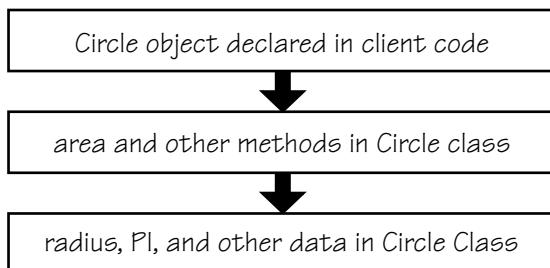
In object-oriented programming, an *object* stores data and can perform actions and provide communication. The *state* of an object refers to the data it stores. The *behavior* of an object is defined by the action and communication it provides.

Objects often model, or simulate, real-world things. For example, consider a circle shape. To create a Circle object modeled after the circle shape, we analyze the state and behavior of the shape. A circle is defined by its radius, so this will make up the state of the object. A circle shape doesn't do much in the way of actions, but a Circle object could change its radius, calculate its area, and tell us what its radius is. These actions will make up the behavior of a Circle object.

**TIP** A class is an abstract data type, which was discussed in Chapter 4.

*encapsulation  
information hiding*

An object is an *instance* of a class. A *class* is a data type that defines variables for the state of an object and methods for an object's behavior. Good programming style dictates that the state of an object can only be changed through its behavior. For example, to change the radius of a Circle object, a method for changing the radius variable must be called. Protecting an object's data is called *encapsulation*. Encapsulation is also called *information hiding* because the object hides certain data from code outside the class. For example, a Circle object declared in client code can be visualized as:



### *client code*

**TIP** In Java, the controlling class is the client code.

*Client code* refers to an application that uses one or more classes. The client can access the methods of the class, but cannot directly access the data defined in the class. This reinforces that the state of an object can only be changed through its behavior.

TestCircle is client code. It uses the Circle class:

```
public class TestCircle {

 public static void main(String[] args) {
 Circle spot = new Circle();

 spot.setRadius(5);

 System.out.println("Circle radius: " + spot.getRadius());
 System.out.println("Circle area: " + spot.area());
 }
}
```

In the TestCircle application, a Circle object named `spot` is instantiated. The object `spot` uses behavior `setRadius()` to change the state of the object, making the radius of the circle 5. Two other behaviors are implemented to produce the application output:

```
Circle radius: 5.0
Circle area: 78.5
```

## Designing and Writing a Class

### **Functional Decomposition**

The process of creating clearly defined functions, or behavior, for a class is sometimes called *functional decomposition*. A well-written class has been functionally decomposed into a set of methods that cannot be simplified further.

Designing a class requires choosing the data the object will store and determining the actions and communication the object will provide. The design should include variable names and method names along with a description of the method and any required parameters. For example, the Circle class design appears similar to:

```
Circle
variables: radius, PI
methods:
setRadius – changes the radius. Requires one
parameter for radius.
getRadius – returns the circle radius.
area – returns the area of the circle based on
the current radius.
```

### *class declaration, body*

### *constructor member*

A class is written in a separate file and consists of a declaration and a body. The *class declaration* includes the access level, the keyword `class`, and the class name. The *class body* contains variables, constructors, and methods. *Constructors* are used to initialize variables in a class. Variables and methods are called the *members* of a class. A class takes the form:

```
<access_level> class <name> {
 <variables>
 <constructors>
 <methods>
}
```

### Organizing Files

Each class is written in a separate file. The client code and the classes it uses are then compiled together as part of a project.

### Interface

The public methods of a class define the *interface* of an object. The interface is how client code can interact with an object.

### naming conventions

The Circle class code is based on the design on the previous page:

```
/*
 * Circle class.
 */
public class Circle {
 private static final double PI = 3.14;
 private double radius;

 /**
 * constructor
 * pre: none
 * post: A Circle object created. Radius initialized to 1.
 */
 public Circle() {
 radius = 1; //default radius
 }

 /**
 * Changes the radius of the circle.
 * pre: none
 * post: Radius has been changed.
 */
 public void setRadius(double newRadius) {
 radius = newRadius;
 }

 /**
 * Calculates the area of the circle.
 * pre: none
 * post: The area of the circle has been returned.
 */
 public double area() {
 double circleArea;
 circleArea = PI * radius * radius;
 return(circleArea);
 }

 /**
 * Returns the radius of the circle.
 * pre: none
 * post: The radius of the circle has been returned.
 */
 public double getRadius() {
 return(radius);
 }
}
```

The Circle class has access level `public` which means that it is visible to other classes and can be used to instantiate objects in those classes. The class name is `Circle`. A class name should be a noun, begin with an uppercase letter, and each word within the name should also begin with an uppercase letter. Class names may not contain spaces.

The body of a class starts with an opening brace (`{`) and ends with a closing brace (`}`). Member variables are declared after the opening brace, and outside of any methods. Variable declarations in the body of a class have a local scope that extends from the opening brace of the class body to the closing. Note that the Circle class also has a member variable that is a constant.

**TIP** Access modifiers and visibility were introduced in Chapter 7.

The visibility of a member variable is controlled with an access modifier. Declaring a variable as `private` makes it visible to the class, but not to client code. This encapsulates the data and provides information hiding. For example, the `Circle` class contains a `private` variable `radius` that can be used by any of the methods of the class, but cannot be directly accessed by statements in the client code where the `Circle` object was created.

A constructor is automatically called when an object is created. The constructor is where variables are initialized. Variables that are not initialized may contain data that could generate a run-time error when a method of the class is executed.

#### **accessor method**

#### **modifier method**

#### **helper method**

The methods in a class are accessor methods, modifier methods, or helper methods. *Accessor methods* are called to determine the value of a variable. For example, in the `Circle` class, `getRadius()` is an accessor method. It returns the value of the variable `radius`. A *modifier method* is called to change the value of a variable. In the `Circle` class, `setRadius()` is a modifier method. It assigns a value passed in a parameter to the variable `radius`. Accessor and modifier methods have access level `public` so that they may be called from the class where the `Circle` object was created.

*Helper methods* are called from within a class by other methods. They are used to help complete a task and have access level `private`. The `Circle` class does not contain helper methods.

An application that includes `Circle` objects can include statements that call the `public` methods, but statements that refer to the `private` members will generate a compiler error.

## Review: Circle – part 1 of 4

Modify the `Circle` class to include a member method named `circumference`. The `circumference()` method should return the circumference of the circle ( $2\pi r$ ). Test the class with the following client code:

```
public static void main(String[] args) {
 Circle spot = new Circle();
 spot.setRadius(3);
 System.out.println("Circle radius: " + spot.getRadius());
 System.out.println("Circle circumference: " + spot.circumference());
```

## Review: Coin – part 1 of 2

Create a `Coin` class that includes a variable `faceUp` that stores either a 0 for heads up or 1 for tails up, an accessor method named `showFace()` that returns a 0 if the coin is heads up or a 1 if the coin is tails up, and a modifier method named `flipCoin()` that assigns a random integer between 0 and 1, inclusive, to the variable `faceUp`. Test the class with the following client code:

```
public static void main(String[] args) {
 Coin nickel = new Coin();
 if (nickel.flipCoin() == 0) {
 System.out.println("Heads up!");
 } else {
 System.out.println("Tails up!");
 }
}
```

# Writing Constructors

The constructor of a class is automatically executed when an object is instantiated. Once an object is instantiated, the method members of the class can be called in any order. Unexpected results may occur if an accessor method is called before a member variable has been set to a valid value. To prevent this, variables should be initialized in the constructor.

A constructor takes the form:

```
public <class name>(<parameters>) {
 <statements>
}
```

The constructor of a class does not have a return type and always has the same name as the class. When a constructor contains parameters, they are separated by commas.

## overloading constructors

Constructors can be overloaded to provide more options for instantiating an object. For example, if the radius of the circle object is known when the Circle object is created, it would be more efficient to assign the value to `radius` when the object is created:

```
Circle spot = new Circle(5);
```

A constructor can be added to the Circle class to handle creating an object with a parameter that contains the circle radius:

```
/**
 * Circle class.
 */
public class Circle {
 private static final double PI = 3.14;
 private double radius;

 /**
 * constructor
 * pre: none
 * post: A Circle object created. Radius initialized to 1.
 */
 public Circle() {
 radius = 1; //default radius
 }

 /**
 * constructor
 * pre: none
 * post: A Circle object created with radius r.
 */
 public Circle(double r) {
 radius = r;
 }
}
```

*...rest of Circle class*

When a class contains more than one constructor, the compiler uses the number and types of parameters to determine which constructor to execute.

## Review: Circle – part 2 of 4

Modify the Circle class to include an overloaded constructor that accepts the radius of the Circle object, as shown in the previous section.

## Review: Rectangle – part 1 of 5

Design and then create a Rectangle class that has overloaded constructors. The first constructor requires no parameters. The second has two parameters, one for length and a second for width. Member variables store the length and width of the rectangle, and member methods assign and retrieve the length and width and return the area and perimeter of the rectangle. Test the class by writing appropriate client code.

## Instance and Class Members

*instance variable  
class variable*

Each object, or instance, of a class has its own copy of variables called *instance variables*. For example, the Circle class contains the instance variable `radius`. A class may also contain class variables. A *class variable* is declared with the keyword `static` and only one copy is maintained for all objects to refer to. For example, the Circle class contains the class variable `PI`. Note that because `PI` is a constant, it also includes the keyword `final`:

```
/**
 * Circle class.
 */
public class Circle {
 private static final double PI = 3.14; //class constant
 private double radius; //instance variable

 ...rest of Circle class
```

In the statements below, two Circle objects are instantiated. Each instance has its own copy of the instance variable `radius`, but both objects refer to the same copy of the class constant `PI`:

```
Circle spot1 = new Circle(2); radius [2] PI → [3.14]
Circle spot2 = new Circle(5); radius [5] PI
```

*instance methods*

*class methods*

Methods can be either instance methods or class methods. Accessor and modifier methods are *instance methods* because they change the state of an object. They must be called from an instance of a class. Chapter 7 introduced *class methods* that are declared with the keyword `static`. Class methods can be called from the class itself, rather than an object of the class, to perform a task. For example, consider the Circle class with the following class method added:

```
/**
 * Displays the formula for the area of a circle.
 * pre: none
 * post: The formula for area of a circle has been displayed.
 */
public static void displayAreaFormula() {
 System.out.println("The formula for the area of a
 circle is a=Pi*r*r");
}
```

The following client code calls the `displayAreaFormula()` class method:

```
public class TestCircle {

 public static void main(String[] args) {
 Circle spot = new Circle(5);

 System.out.println("Circle radius: " + spot.getRadius());
 System.out.println("Circle area: " + spot.area());
 Circle.displayAreaFormula();
 }
}
```

**TIP** Class methods cannot be used to change the value of an instance variable.

The class method is called from the class itself (`Circle`) rather than an object of the class. The `TestCircle` application displays the following output:

```
Circle radius: 5.0
Circle area: 78.5
The formula for the area of a circle is a=Pi*r*r
```

To summarize the differences between instance and class members:

- instance variables are created each time an object is declared.
- class variables and constants are created once for the class and then objects of the class refer to this copy.
- instance methods can only be called from an object of the class.
- class methods can be called from the class itself.

## Review: Circle – part 3 of 4

Modify the `Circle` class to include a class method named `displayAreaFormula`, as shown in the previous section. Modify existing client code to test the new method.

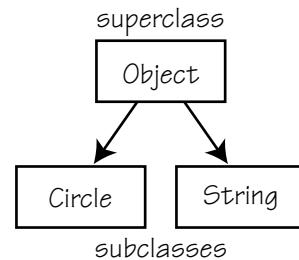
## Review: Rectangle – part 2 of 5

Modify the `Rectangle` class to include a class method named `displayAreaFormula`. Modify existing client code to test the new method.

## The Object Class

**superclass**  
**subclass**

The `Object` class is the *superclass* of all other classes. Classes, such as `Circle` and `String`, are *subclasses* of `Object`:



## inherit

Subclasses *inherit*, or receive, the methods of its superclass. The Object class includes methods for comparing objects and representing an object as a string:

```
Class Object (java.lang.Object)
Method
equals(Object obj)
 returns true if obj is equal to the object.
toString() returns a String that represents the object.
```

**TIP** If a subclass does not override the equals() and toString() methods, then the Object class methods are used.

## override

A subclass typically contains its own version of the equals() and toString() superclass methods to better suit the object of the subclass. For example, two Circle objects are equal when they both have the same radius, and two String objects are equal when they consist of the same set of characters.

When a subclass redefines a superclass method, the subclass method is said to *override* the superclass method. The Circle class should contain an equals() method that compares the state of the object to another Circle object and a toString() method that returns a String describing the object:

```
/*
 * Determines if the object is equal to another
 * Circle object.
 * pre: c is a Circle object.
 * post: true has been returned if the objects have
 * the same radii. false has been returned otherwise.
 */
public boolean equals(Object c) {
 Circle testObj = (Circle)c;

 if (testObj.getRadius() == radius) {
 return(true);
 } else {
 return(false);
 }
}

/*
 * Returns a String that represents the Circle object.
 * pre: none
 * post: A string representing the Circle object has
 * been returned.
 */
public String toString() {
 String circleString;

 circleString = "Circle has radius " + radius;
 return(circleString);
}
```

## object casting

The equals() method requires an Object parameter. In the body of the method, the obj parameter must be cast as the appropriate type, in this case Circle, and then assigned to an object of the appropriate type. If an Object variable is cast with an incompatible class, then the exception ClassCastException will be generated. To convert an object to its superclass Object, no class casting is required.

## ClassCastException

The code below creates two Circle objects, compares them, and displays information about the objects. An object's `toString()` method is invoked when an object is passed to the `println()` method:

```
public static void main(String[] args) {
 Circle spot1 = new Circle(3);
 Circle spot2 = new Circle(4);

 if (spot1.equals(spot2)) {
 System.out.println("Objects are equal.");
 } else {
 System.out.println("Objects are not equal.");
 }
 System.out.println(spot1);
 System.out.println(spot2);
}
```

**TIP** The concatenation operator `+` also invokes the `toString()` method of an object.

The code above displays the output:

```
Objects are not equal.
Circle has radius 3.0
Circle has radius 4.0
```

## Review: Circle – part 4 of 4

Modify the Circle class to override the `equals()` and `toString()` methods, as shown in the previous section. Modify existing client code to test the new methods.

## Review: Rectangle – part 3 of 5

Modify the Rectangle class to override the `equals()` and `toString()` methods. Two rectangles are equal when they both have the same length and width. Modify the existing client code to test the new method.

## Review: Coin – part 2 of 2

Modify the Coin class to override the `toString()` method so that it indicates whether the coin is face up or face down. For example, “The coin is face up.” Modify existing client code to test the new method.

*has-a relationship*

## Classes Using Classes

A class may contain member variables that are class data types. Complex data can be easily represented in this way. A class that contains class member variables demonstrates a *has-a relationship*. The class “has a” class. For example, a class with a String member variable demonstrates a has-a relationship.

The Bank program specification on the next page is best implemented with two classes. One class (Account) has a member variable (Customer) for representing the customers that hold the accounts:

A bank maintains accounts where account holders can deposit money and withdraw money. The account holders are customers with a first and last name and complete address.

## Nested Classes and Inner Classes

A *nested class* is a class defined in another class as a member of that class. The member class has access to other data members, just as other members of the class. A nested class is also called an *inner class*, unless it is declared static.

A model of Bank includes an Account object that stores customer data and a current balance. Account methods should return a balance, perform deposits, and perform withdrawals. If an Account object is passed to the `println()` method, customer data and their balance should be displayed.

The designs for the Bank classes are:

Account

variables: `balance`, `Customer cust`

methods:

`getBalance` – returns the current balance.

`deposit` – increases the balance. Requires parameter for amount.

`withdrawal` – decreases the balance. Requires parameter for amount. If balance is less than withdrawal, then balance left unchanged.

`toString` – returns a string with customer information and current balance.

Customer

variables: `firstName`, `lastName`, `street`, `city`, `state`, `zip`

methods:

`toString()` – returns a string with customer information.

The Bank client code uses the class designs and looks similar to:

```
import java.util.Scanner;
import java.text.NumberFormat;

public class Bank {

 public static void main(String[] args) {
 Account munozAccount = new Account(250, "Maria", "Munoz", "110 Glades Road",
 "Mytown", "FL", "33445");
 Scanner input = new Scanner(System.in);
 double data;
 NumberFormat money = NumberFormat.getCurrencyInstance();

 System.out.println(munozAccount);

 System.out.print("Enter deposit amount: ");
 data = input.nextDouble();
 munozAccount.deposit(data);
 System.out.println("Balance is: " + money.format(munozAccount.getBalance()));

 System.out.print("Enter withdrawal amount: ");
 data = input.nextDouble();
 munozAccount.withdrawal(data);
 System.out.println("Balance is: " + money.format(munozAccount.getBalance()));
 }
}
```

The Account class is implemented below:

```
import java.text.NumberFormat;

public class Account {
 private double balance;
 private Customer cust;

 /**
 * constructor
 * pre: none
 * post: An account created. Balance and
 * customer data initialized with parameters.
 */
 public Account(double bal, String fName, String lName,
 String str, String city, String st, String zip) {
 balance = bal;
 cust = new Customer(fName, lName, str, city, st, zip);
 }

 /**
 * Returns the current balance.
 * pre: none
 * post: The account balance has been returned.
 */
 public double getBalance() {
 return(balance);
 }

 /**
 * A deposit is made to the account.
 * pre: none
 * post: The balance has been increased by the amount of the deposit.
 */
 public void deposit(double amt) {
 balance += amt;
 }

 /**
 * A withdrawal is made from the account if there is enough money.
 * pre: none
 * post: The balance has been decreased by the amount withdrawn.
 */
 public void withdrawal(double amt) {
 if (amt <= balance) {
 balance -= amt;
 } else {
 System.out.println("Not enough money in account.");
 }
 }
}
```

### this

The keyword `this` can be used to distinguish between a parameter and a member variable. For example, it can be convenient to use the same name for both a method parameter and a member variable in a class, in which case, the member variable is preceded by `this`. If in the Account class, the constructor used `double balance` as a parameter, then the statement in the body must be written as: `this.balance = balance;`

```

 /**
 * Returns a String that represents the Account object.
 * pre: none
 * post: A string representing the Account object has
 * been returned.
 */
 public String toString() {
 String accountString;
 NumberFormat money = NumberFormat.getCurrencyInstance();

 accountString = cust.toString();
 accountString += "Current balance is " + money.format(balance);
 return(accountString);
 }
}

```

The Customer class is implemented below:

```

public class Customer {
 private String firstName, lastName, street, city,
 state, zip;

 /**
 * constructor
 * pre: none
 * post: A Customer object has been created.
 * Customer data has been initialized with parameters.
 */
 public Customer(String fName, String lName, String str,
 String c, String s, String z) {
 firstName = fName;
 lastName = lName;
 street = str;
 city = c;
 state = s;
 zip = z;
 }

 /**
 * Returns a String that represents the Customer object.
 * pre: none
 * post: A string representing the Account object has
 * been returned.
 */
 public String toString() {
 String custString;

 custString = firstName + " " + lastName + "\n";
 custString += street + "\n";
 custString += city + ", " + state + " " + zip + "\n";
 return(custString);
 }
}

```

Running the Bank application produces output similar to:

```
Maria Munoz
110 Glades Road
Mytown, FL 33445
Current balance is $250
Enter deposit amount: 100
Balance is: $350
Enter withdrawal amount: 400
Not enough money in account.
Balance is: $350
```

## Review: Bank

Modify the Customer class to include changeStreet(), changeCity(), changeState(), and changeZip() methods.  
Modify the Account class to include a changeAddress() method that has street, city, state, and zip parameters.  
Modify the Bank application to test the changeAddress() method.

## Object-Oriented Development

Object-oriented programming requires that the solution to a task be implemented as a system of objects. In this system, objects communicate with other objects to provide a solution to the task. This approach to creating software is called *object-oriented development*.

**TIP** The JRE was first discussed in Chapter 4.

*reusability*

In object-oriented development, the programmer reads the specification and selects objects to model the specification. Some of these objects will require new classes designed and written by the programmer. Other objects can be created from existing classes previously written by the programmer or by other programmers. For example, the JRE contains numerous classes for use in a Java application. *Reusability* is an important feature of object-oriented programming because it reduces development time and decreases the likelihood of bugs.

To demonstrate object-oriented development, consider the following Carnival program specification:

A carnival has many games that are similar in nature. These games allow the player three tries, and the player who is successful all three times is a winner. For example, the Balloon Dart Toss game allows the player to throw three darts at a wall of balloons. If each dart pops a balloon, then the player is a winner. The Ring Toss and Break A Plate games work similarly.

Every player gets a prize. There are winning prizes and consolation prizes. The Balloon Dart Toss prizes are tiger plush and sticker. The Ring Toss prizes are bear key chain and pencil, and the Break A Plate prizes are pig plush and plastic dinosaur. The Balloon Dart Toss and Ring Toss games are \$2 to play. The Break A Plate game costs \$1.50.

The player comes to the carnival with some spending money and can play games until the money runs out. The player also holds onto all the prizes won.

The Carnival application should produce output similar to the following when Shonda has \$5 spending money and Luis has \$3:

```
Shonda goes to Balloon Dart Toss. prize won: tiger plush
Luis goes to Ring Toss. prize won: bear keychain
Shonda goes to Ring Toss. prize won: pencil
Luis goes to Break a Plate. Sorry, not enough money to play.
Shonda won: pencil, tiger plush
Luis won: bear keychain
```

### *selecting objects for the model*

In the first step of object-oriented development, objects are selected to model the specification. In this case, the carnival can be modeled with game booth objects and player objects. A game booth object should store data about the cost of playing the game, the winning prize, and the consolation prize. Game booth methods should start the game and give the cost to play. A player object should store data about the spending money of the player and the prizes won. Player methods should play the game and show the list of prizes won.

### *designing objects*

The designs for the Carnival classes are:

#### *GameBooth*

*variables: cost, firstPrize, consolationPrize*

*methods:*

*start – plays the game and returns the prize won.  
getCost – returns the cost of playing the game.*

#### *Player*

*variables: spendingMoney, prizesWon*

*methods:*

*play – determines if player has enough money to  
play the game, decreases money by cost of  
game, and adds prize won to prizes list.  
showPrizes – returns the prize list.*

**client code** The Carnival client code uses the class designs and looks similar to:

```
GameBooth balloonDartToss = new GameBooth(2,"tiger plush", "sticker");
GameBooth ringToss = new GameBooth(2,"bear keychain", "pencil");
GameBooth breakAPlate = new GameBooth(1.5, "pig plush", "plastic dinosaur");
Player shonda = new Player(5); //$/5 spending money
Player luis = new Player(3); //$/3 spending money

System.out.print("Shonda goes to Balloon Dart Toss. ");
System.out.println(shonda.play(balloonDartToss));

System.out.print("Luis goes to Ring Toss. ");
System.out.println(luis.play(ringToss));

System.out.print("Shonda goes to Ring Toss. ");
System.out.println(shonda.play(ringToss));

System.out.print("Luis goes to Break A Plate. ");
System.out.println(luis.play(breakAPlate));

System.out.println("Shonda won: " + shonda.showPrizes());
System.out.println("Luis won: " + luis.showPrizes());
```

Note how simple the application appears. All the work is being done by the objects, rather than with individual statements in the main() method.

**modular**

The Carnival application, like other object-oriented applications, is *modular*. It uses components that are separately written and maintained.

**message**

Another aspect of object-oriented development is that objects send information to other objects to perform a task. When information is passed from one object to another, the object is said to be passing a *message*. For example, in the pseudocode above, the Player objects are passed a message that includes the cost of game and the prize the player won.

**implementing the classes**

The GameBooth class is implemented below. Note that in the start() method, the player's throws are simulated with random numbers. The player is said to win if three ones are generated:

```
import java.util.Random;

public class GameBooth {
 private double cost;
 private String firstPrize, consolationPrize;

 /**
 * constructor
 * pre: none
 * post: A GameBooth object created.
 * The cost and prizes are set.
 */
 public GameBooth(double charge, String p1, String p2) {
 cost = charge;
 firstPrize = p1;
 consolationPrize = p2;
 }
```

```

 /**
 * Game is played and prize awarded.
 * pre: none
 * post: Player had three tries. Player successful all
 * three times received the first prize. A consolation
 * prize has been awarded otherwise.
 */
 public String start() {
 int toss;
 int successes = 0;
 Random rand = new Random();

 /* play game */
 for (int i = 0; i < 3; i++) { //player gets three tries
 toss = rand.nextInt(2);
 if (toss == 1) {
 successes += 1; //1 is a successful toss
 }
 }

 /* award prize */
 if (successes == 3) {
 return(firstPrize);
 } else {
 return(consolationPrize);
 }
 }

 /**
 * Returns the cost to play the game.
 * pre: none
 * post: Cost of the game has been returned.
 */
 public double getCost() {
 return(cost);
 }
}

```

The Player class is implemented below:

```

public class Player {
 private double spendingMoney;
 private String prizesWon;

 /**
 * constructor
 * pre: none
 * post: A Player object created. Spending money given to
 * player. The prizes won set to none.
 */
 public Player(double money) {
 spendingMoney = money;
 prizesWon = "";
 }
}

```

```

 /**
 * Player pays for and then plays a game.
 * pre: none
 * post: Player's spending money decreased by cost of game.
 * The player has a new prize added to existing prizes.
 */
 public String play(GameBooth game) {
 String newPrize;

 if (game.getCost() > spendingMoney) {
 return("Sorry, not enough money to play.");
 } else {
 spendingMoney -= game.getCost(); //pay for game
 newPrize = game.start(); //play game
 prizesWon = newPrize + ", " + prizesWon;
 return("prize won: " + newPrize);
 }
 }

 /**
 * Returns the list of prizes won.
 * pre: none
 * post: The list of prizes has been returned.
 */
 public String showPrizes() {
 return(prizesWon);
 }
}

```

Running the Carnival application produces output similar to:

```

Shonda goes to Balloon Dart Toss. prize won: sticker
Luis goes to Ring Toss. prize won: pencil
Shonda goes to Ring Toss. prize won: pencil
Luis goes to Break A Plate. Sorry, not enough money to play.
Shonda won: pencil, sticker,
Luis won: pencil,

```

Although the classes may look long, once written they are available for many different implementations of a Carnival or another application that involves games.

## Review: Carnival

Modify the Player class to override the `toString()` method. When a Player object is passed to the `println()` method, a message should display how much money the player has left and the prizes won so far.

Modify the GameBooth class to keep track of the number of prizes awarded. There should be separate totals for the first prizes awarded and the consolation prizes awarded. Add a method to the GameBooth class named `prizesAwarded()` that displays the number of first prizes and the number of consolation prizes given away.

Modify the Carnival client code to pass the Player objects to `println()` in the last two statements, and in separate statements, display how many prizes were given away by each booth.

# Chapter 8 Case Study

**TIP** An RPS application was also developed for the Chapter 5 Case Study.

In this case study, a Rock Paper Scissors game will be created using object-oriented development. Rock Paper Scissors is a popular game played between two individuals for decision making or just for competitive fun. The rules of the game are Rock dulls Scissors (Rock wins), Scissors cuts Paper (Scissors wins), and Paper covers Rock (Paper wins). The two players make a “throw” at the same time. The hand signals thrown by the players are then compared to the rules of the game to determine the winner. In the computerized version, the user plays against the computer.

## RPS2 Specification

The computerized version of the Rock Paper Scissors game is played by one user that “throws” either rock, paper, or scissors. The game then randomly selects either rock, paper, or scissors for the computer’s “throw” and the winner is determined by comparing the two choices. Rock wins over scissors, scissors wins over paper, and rock wins over scissors. The player can initially choose to play multiple rounds. At the end of the rounds, an overall winner is declared.

The RPS2 interface should show the result of each round and the overall winner. The RPS2 output sketch:

```
How many rounds? 3
Enter your throw (1=Rock, 2=Paper, 3=Scissors): 3
You throw SCISSORS.
Computer throws PAPER.
You win!
Enter your throw (1=Rock, 2=Paper, 3=Scissors): 3
You throw SCISSORS.
Computer throws ROCK.
Computer wins!
Enter your throw (1=Rock, 2=Paper, 3=Scissors): 3
You throw PAPER.
Computer throws ROCK.
You win!
Computer wins 1. You win 2.
You win!
```

The RPS2 algorithm:

1. Prompt the player for the number of rounds.
2. For each round:

```
Prompt for the player's throw.
Generate the computer's throw.
Announce the winner of the round.
```

3. Announce an overall winner.

## RPS2 Code Design

The RPS2 application can be modeled with a player object and a game object. The player object should store the player's throw (either rock, paper, or scissors) and contain methods that make and return the player's throw. The game object should store the computer's throw, the number of computer wins, and the number of player wins and contain methods that make and return the computer's throw, determine the winner of each round, and determine an overall winner.

The designs for the RPS2 classes are:

### RPSPlayer

variables: playerName, playerThrow

methods:

makeThrow – prompts player for throw.  
getThrow – returns the player's throw.

### RPSGame

variable: compThrow, playerWins, playerThrow

methods:

makeCompThrow – generates the computer's throw.  
getCompThrow – returns the computer's throw.  
announceWinner – displays a message indicating the throws  
and the winner. Requires parameters for  
player throw and player name.  
bigWinner – determine overall winner.

Based on the algorithm and the class designs, the RPS2 code design will include two objects and a loop. The pseudocode for the RPS2 client code follows:

```
declare game object
declare player object

prompt player for number of rounds
for (i = 0; i < rounds; i++) {
 prompt player for throw
 player.makeThrow(playerThrow);
 gameObject.makeThrow();
 gameObject.announceWinner(playerObject.getThrow());
}
gameObject.bigWinner
```

## RPS2 Implementation

The RPS2 implementation involves creating three files. One file contains the client code and the other two files are the classes.

The RPS2Player class is implemented below:

```
/**
 * models the player in a game of RPS
 */
public class RPSPPlayer {
 private int playerThrow; //ROCK=1, PAPER=2, SCISSORS=3

 /**
 * constructor
 * pre: none
 * post: RPSPPlayer object created. The player is given a
 * default throw.
 */
 public RPSPPlayer() {
 playerThrow = 1; //default throw
 }

 /**
 * Sets the player's throw.
 * pre: newThrow is the integer 1, 2, or 3.
 * post: Player's throw has been made.
 */
 public void makeThrow(int newThrow){
 playerThrow = newThrow;
 }

 /**
 * Returns the player's throw.
 * pre: none
 * post: Player's throw has been returned.
 */
 public int getThrow() {
 return(playerThrow);
 }
}
```

The RPSGame class is implemented below:

```
/*
 * Models a game of RPS
 */

import java.util.Random;

public class RPSGame {
 public static final int ROCK = 1, PAPER = 2, SCISSORS = 3;
 private int compThrow;
 private int playerWins = 0, computerWins = 0;

 /**
 * constructor
 * pre: none
 * post: RPSGame object created. Computer throw generated.
 */
 public RPSGame() {
 Random rand = new Random();

 compThrow = rand.nextInt(3) + 1; //random int between 1 and 3
 playerWins = 0;
 computerWins = 0;
 }

 /**
 * Computer's throw is generated (ROCK, PAPER, or SCISSORS)
 * pre: none
 * post: Computer's throw has been made.
 */
 public void makeCompThrow(){
 Random rand = new Random();

 compThrow = rand.nextInt(3) + 1; //random int between 1 and 3
 }

 /**
 * Returns the computer's throw.
 * pre: none
 * post: Computer's throw has been returned.
 */
 public int getCompThrow() {
 return(compThrow);
 }

 /**
 * Determines the winner of the round.
 * pre: playerThrow is the integer 1, 2, or 3.
 * post: Displays a message indicating throws. Compares player's
 * throw to computer's throw and displays a message indicating
 * the winner.
 */
 public void announceWinner(int playerThrow) {

 /* Inform player of throws */
 System.out.print("You throw ");
 switch (playerThrow) {
 case ROCK: System.out.println("ROCK."); break;
 case PAPER: System.out.println("PAPER."); break;
 case SCISSORS: System.out.println("SCISSORS."); break;
 }
 }
}
```

```

 System.out.print("Computer throws ");
 switch (compThrow) {
 case ROCK: System.out.println("ROCK."); break;
 case PAPER: System.out.println("PAPER."); break;
 case SCISSORS: System.out.println("SCISSORS."); break;
 }

 /* Determine and announce winner */
 if (playerThrow == ROCK && compThrow == ROCK) {
 System.out.println("It's a draw!");
 } else if (playerThrow == ROCK && compThrow == PAPER) {
 System.out.println("Computer wins!");
 computerWins += 1;
 } else if (playerThrow == ROCK && compThrow == SCISSORS) {
 System.out.println("You win!");
 playerWins += 1;
 }

 if (playerThrow == PAPER && compThrow == ROCK) {
 System.out.println("You win!");
 playerWins += 1;
 } else if (playerThrow == PAPER && compThrow == PAPER) {
 System.out.println("It's a draw!");
 } else if (playerThrow == PAPER && compThrow == SCISSORS) {
 System.out.println("Computer wins!");
 computerWins += 1;
 }

 if (playerThrow == SCISSORS && compThrow == ROCK) {
 System.out.println("Computer wins!");
 computerWins += 1;
 } else if (playerThrow == SCISSORS && compThrow == PAPER) {
 System.out.println("You win!");
 playerWins += 1;
 } else if (playerThrow == SCISSORS && compThrow == SCISSORS) {
 System.out.println("It's a draw!");
 }
 }

 /**
 * Displays the overall winner.
 * pre: none
 * post: Computer and player wins compared and
 * an overall winner announced.
 */
 public void bigWinner() {
 if (computerWins > playerWins){
 System.out.println("Computer wins!");
 } else if (playerWins > computerWins){
 System.out.println("You win!");
 } else {
 System.out.println("It's a draw!");
 }
 }
}

```

The RPS2 client code follows:

```
/*
 * RPS2.java
 */

import java.util.Scanner;

/**
 * Computer plays Rock Paper Scissors against one player.
 */
public class RPS2 {

 public static void main(String[] args) {
 RPSGame rps = new RPSGame();
 RPSPlayer rpsOpponent = new RPSPlayer();
 int rounds;
 int playerThrow;
 Scanner input = new Scanner(System.in);

 /* play RPS */
 System.out.print("How many rounds? ");
 rounds = input.nextInt();
 for (int i = 0; i < rounds; i++) {
 System.out.print("Enter your throw (ROCK=1,
 PAPER=2, SCISSORS=3): ");
 playerThrow = input.nextInt();
 rpsOpponent.makeThrow(playerThrow);

 rps.makeCompThrow();
 rps.announceWinner(rpsOpponent.getThrow());
 }
 rps.bigWinner();
 }
}
```

Note how concise the client code is. The RPS2 application uses objects to perform all the work.

Although the classes may look long, once written they are available for many different implementations of the RPS game. Client code can be written to use the classes in many different ways. For example, multiple players and games can be instantiated for tournaments.

### RPS2 Testing and Debugging

When a new class is written, client code should be written to test the class. For the RPSGame class, client code should test all the possible throw combinations, similar to the testing discussed in the Chapter 5 Case Study.

## Review: RPS2 – part 1 of 2

Modify the RPSPlayer class to include a `playerName` variable and methods named `assignName` and `getName`. The `assignName()` method has a String parameter `name` that is assigned to `playerName`. The `getName()` method returns the value of `playerName`. Modify the `announceWinner()` and `bigWinner()` methods in the RPSGame class to include a String parameter `name` that is the player's name. Change the messages displayed in the `announceWinner()` and `bigWinner()` methods to include the player's name rather than the word "You". Modifying the two classes should produce output similar to the sketch below:

```
Enter your name: Lucy
How many rounds? 3

Enter your throw (1=Rock, 2=Paper, 3=Scissors): 3
Lucy throws SCISSORS.
Computer throws PAPER.
Lucy wins!

Enter your throw (1=Rock, 2=Paper, 3=Scissors): 3
Lucy throws SCISSORS.
Computer throws ROCK.
Computer wins!

Enter your throw (1=Rock, 2=Paper, 3=Scissors): 3
Lucy throws PAPER.
Computer throws ROCK.
Lucy wins!

Computer wins 1. Lucy wins 2.
Lucy is the winner!
```

## Review: RPS2 – part 2 of 2

Modify the RPS2 client code to perform error checking on the player's input. Have the client code verify that the user has entered a 1, 2, or 3 for a throw before passing the entered value to the `makeThrow()` method.

## Chapter Summary

This chapter introduced writing and designing classes. Classes are the data types of objects. An object has a state (data) and behavior (actions and communication in the form of methods). An important aspect of object-oriented programming is encapsulation, also called information hiding. In OOP, classes are written to encasulate, or hide, data from outside code. Client code is code that uses one or more classes.

A class includes a class declaration, variables, constructors, and methods. The class declaration includes the access level, the keyword `class`, and a name. Variables and methods are the members of a class. Variables are the data members and should be declared `private`. Accessor and modifier methods are declared `public`, while helper methods are declared `private`. Constructors are used to initialize variables and can be overloaded so that objects can be declared with varying numbers of parameters.

The variables and methods of a class are either instance or class members. Instance members are copied for each instance of a class. Only one copy of a class member exists for the class. Every object of a class refers to the same class member. The keyword `static` is used for a class member declaration. Class methods can be called from the class itself. An object of the class can call either instance or class members.

Every class is a subclass of the `Object` class. The `Object` class could also be called the superclass of all other classes. The `equals()` and `toString()` methods in the `Object` class are inherited by all other classes. In most cases, these methods should be redefined in subclasses.

An object that contains an object is said to demonstrate a has-a relationship. Any class that contains a `String` data member demonstrates a has-a relationship.

Object-oriented development requires the solution to a task be implemented as a system of objects. In this system, objects pass messages back and forth to provide a solution to the task.

This chapter discussed several important aspects of the object-oriented paradigm, including encapsulation, reusability, and modularity.

The code convention introduced in this chapter is:

- Class names should be a noun, begin with an uppercase letter, and each word within the name should also begin with an uppercase letter.

# Vocabulary

**Accessor method** A method of a class that is used to determine the value of a variable member. Accessor methods have access level `public`.

**Behavior** The action and communication an object provides.

**Class** A data type that defines variables for the state of an object and methods for an object's behavior.

**Class body** The variables, constructors, and methods that implement a class.

**ClassCastException** An exception thrown when an object variable is cast with an incompatible class.

**Class declaration** The first line of a class, which contains the access level, the keyword `class`, and the class name.

**Class method** A method of a class that can be called from the class itself. It cannot change the state of an object. Class methods include the keyword `static`.

**Class variable** A variable of a class that exists as one copy that all instances of a class refer to. Class variables include the keyword `static`.

**Client code** An application that uses one or more classes.

**Constructor** The part of a class that is used to initialize the variable members of a class.

**Encapsulation** Protecting an object's data from code outside the class.

**Has-a relationship** The relationship demonstrated by a class that contains another class.

**Helper method** A method of a class that is used by other methods in a class to help complete a task. Helper methods have access level `private`.

**Information hiding** Also called encapsulation.

**Inherit** To receive the methods of a superclass.

**Instance** An object of a class.

**Instance method** A method of a class that changes the state of a class. It must be called from an instance of the class.

**Instance variable** A variable of a class that is copied for each instance of the class.

**Member** A variable or method of a class.

**Message** Information passed from one object to another.

**Modifier method** A method of a class that is used to change the value of a variable member. Modifier methods have access level `public`.

**Modular** An application that uses components that are separately written and maintained.

**Object** An instance of a class. An object stores data and can perform actions and provide communication.

**Object casting** To cast an object as the appropriate class.

**Object-oriented development** The solution to a task that is implemented as a system of objects.

**Override** To redefine a method from a superclass in a subclass.

**Reusability** A feature of object-oriented programming that reduces development time and decreases the likelihood of bugs.

**State** The data an object stores.

**Subclass** A class below another class in a class hierarchy. A class that inherits another class.

**Superclass** The upper-most class in a class hierarchy. A class that has subclasses.

**Visibility** The access level of a method.

`class` The keyword used to declare a class.

`public` An access modifier used in the declaration of a class to indicate that the class is visible to client code. Also used in the declaration of class methods to indicate that the method is visible to client code.

`static` The keyword used in the declaration of a variable or method in a class to indicate that the member is a class method.

`private` A keyword used in the declaration of class members when those members should be visible to the class but not to client code.

## Critical Thinking

1. Which members of the Circle class are encapsulated?
2. What name must the constructor of a class have?
3. Explain the difference between the `private` and `public` access modifiers.
4. Consider the following code. Is the last statement valid or invalid? Explain.

```
Circle dot = new Circle(2);
dot.radius = 5;
```
5. Use the following class to answer the questions below:

```
public class Roo {
 private int x;

 public Roo {
 x = 1;
 }

 public void setX(int z) {
 x = z;
 }

 public int getX() {
 return(x);
 }

 public int calculate() {
 x = x * factor();
 return(x);
 }

 private int factor() {
 return(0.12);
 }
}
```

  - a) What is the name of the class?
  - b) What is the name of the data member?
  - c) List the accessor method.
  - d) List the modifier method.
  - e) List the helper method.
  - f) What is the name of the constructor?
  - g) How many method members are there?
6. What is the difference between a class and an object?
7. Imagine a band festival where there are many bands playing—the TwoToos, the EggRolls, and Goop. Each band can TuneUp, PlayMusic, and TakeABow. A set list can be read or created. If this was simulated in an object-oriented program, what would appropriate names be for:
  - a) the class
  - b) the objects
  - c) a data member
  - d) the method members
8. Assume a class for a sports team named Team.
  - a) List three possible object names.
  - b) List three possible method members.
  - c) List three possible data members.
9. Use the following class data member definitions to answer the questions below:

```
public class Moo {
 private double y;
 private static int x;
 private static final z;
 ...
}
```

  - a) Which data member is a constant?
  - b) Which data members are variables?
  - c) Which data member(s) are instance members?
  - d) Which data member(s) are class members?
10. Explain the difference between calling an instance method member and a class method member.
11. Compare and contrast overriding methods to overloading methods.
12. The Customer class in the Bank application also demonstrates a has-a relationship. Explain.
13. How can reusing code decrease the likelihood of bugs in an application?
14. Explain what is meant by passing a message.

### **True/False**

15. Determine if each of the following are true or false. If false, explain why.
- a) The state of an object is described by its methods.
  - b) The behavior of an object is described by its variables.
  - c) An instance of a class is called an object.
  - d) Client code is an application that uses a class.
  - e) Encapsulation means that all the variables in a class are available to client code.
  - f) A constructor is a member of a class.
  - g) A variable that is visible to a class, but not to client code is declared with the keyword `private`.
  - h) An accessor method is called to change the value of a data member.
  - i) A modifier method returns the value of a data member.
  - j) A constructor of a class is automatically called when an object of the class is instantiated.
  - k) A class can contain multiple constructors.
  - l) An instance variable is copied for each instance of a class.
  - m) A class variable is declared with the keyword `public`.
  - n) A class method must be called from an object of the class.
  - o) A class constant is declared with only the keyword `final`.
  - p) The `Object` class is a subclass of all other classes.
  - q) The `toString()` method can be redefined in subclasses.
  - r) Object-oriented development requires that only one object be used in an application.

## Exercises

### Exercise 1

### MySavings

Create a MySavings application that displays a menu of choices for entering pennies, nickels, dimes, and quarters into a piggy bank and then prompts the user to make a selection. The MySavings application should include a PiggyBank object that can add coins to the piggy bank, remove coins, and return the total amount in the bank. Application output should look similar to:

```
1. Show total in bank.
2. Add a penny.
3. Add a nickel.
4. Add a dime.
5. Add a quarter.
6. Take money out of bank.
Enter 0 to quit
Enter you choice: 5
```

### Exercise 2

### DigitExtractor

Create a DigitExtractor application that prompts the user for an integer and then displays the ones, tens, and hundreds digit of the number. The DigitExtractor application should include a Num object that can return the ones digit, tens digit, hundreds digit, and the whole number. Application output should look similar to:

```
Enter an integer: 123
show (W)hole number.
show (O)nes place number.
show (T)tens place number.
show (H)undreds place number.
(Q)uit
Enter you choice: h
The hundreds place digit is: 1

show (W)hole number.
show (O)nes place number.
show (T)tens place number.
show (H)undreds place number.
(Q)uit
Enter you choice: q
```

## Exercise 3

## LunchOrder

Create a LunchOrder application that prompts the user for the number of hamburgers, salads, french fries, and sodas and then displays the total for the order. The LunchOrder application should include a Food object with a constructor that accepts the price, fat, carbs, and fiber for an item. Food methods should return the price of the item and return the fat, carbohydrates, and fiber. Use the chart below for food prices and nutrition information:

| Item         | Price  | Fat(g) | Carbohydrates(g) | Fiber(g) |
|--------------|--------|--------|------------------|----------|
| hamburger    | \$1.85 | 9      | 33               | 1        |
| salad        | \$2.00 | 1      | 11               | 5        |
| french fries | \$1.30 | 11     | 36               | 4        |
| soda         | \$0.95 | 0      | 38               | 0        |

Application output should look similar to:



```
Enter number of hamburgers: 3
Each hamburger has 9.0g of fat, 33.0g of carbs, and 1.0g of fiber.

Enter number of salads: 4
Each salad has 1.0g of fat, 11.0g of carbs, and 5.0g of fiber.

Enter number of fries: 2
French fries have 11.0g of fat, 36.0g of carbs, and 4.0g of fiber.

Enter number of sodas: 5
Each soda has 0.0g of fat, 38.0g of carbs, and 0.0g of fiber.

Your order comes to: $20.90
```

## Exercise 4

## DiceRollGame

In the Dice Roll game, the player begins with a score of 1000. The player is prompted for the number of points to risk and a second prompt asks the player to choose either high or low. The player rolls two dice and the outcome is compared to the player's choice of high or low. If the dice total is between 2 and 6 inclusive, then it is considered "low". A total between 8 and 12 inclusive is "high". A total of 7 is neither high nor low, and the player loses the points at risk. If the player had called correctly, the points at risk are doubled and added to the total points. For a wrong call, the player loses the points at risk. Create a DiceRollGame application that uses a DRPlayer object based on this specification. The DRPlayer object should have two Die member variables that represent the dice. The Die class should use a random number generator to determine the outcome in a roll() method. Application output should look similar to:

```
You have 1000 points.
How many points do you want to risk? (-1 to quit) 10
Make a call (0 for low, 1 for high): 1
You rolled: 10
You now have 1020 points.
How many points do you want to risk? (-1 to quit) 20
Make a call (0 for low, 1 for high): 1
You rolled: 11
You now have 1060 points.
How many points do you want to risk? (-1 to quit) 20
Make a call (0 for low, 1 for high): 1
You rolled: 7
You now have 1040 points.
How many points do you want to risk? (-1 to quit) -1
```

## Exercise 5

## Nim2

The game of Nim starts with a random number of stones between 15 and 30. Two players alternate turns and on each turn may take either 1, 2, or 3 stones from the pile. The player forced to take the last stone loses. Use object-oriented development to create a Nim2 application that allows the user to play Nim against the computer. The Nim2 application and its objects should:

- Generate the number of stones to begin with.
- Allow the player to go first.
- Use a random number generator to determine the number of stones the computer takes.
- Prevent the player and the computer from taking an illegal number of stones. For example, neither should be allowed to take three stones when there are only 1 or 2 left.

## Exercise 6

## GameOf21

In the Game of 21, a player is dealt two cards from a deck of playing cards and then optionally given a third card. The player closest to 21 points without going over is the winner. Use object-oriented development to create a Game of 21 application that allows the user to play the Game of 21 against the computer. The Game of 21 application and its objects should:

- Deal a card from a deck of playing cards by generating a random number between 1 and 13. A 1 corresponds to an Ace, numbers 2 through 10 correspond to those cards, and 11 through 13 correspond to Jack, Queen, and King. The Jack, Queen, and King have a value of 10 in the Game of 21. An Ace can have a value of either 1 or 11.
- Allow the player to stay with two cards or be given a third card.
- Announce the winner.
- Play rounds until the player says to stop.

## Exercise 7

## Bowling

In bowling, a ball is rolled down a lane, also called an alley, at a set of ten pins. A game consists of a bowler bowling for ten frames, where each frame consists of two chances (throws) to knock over all ten pins. Bowling centers often use computers to electronically keep scores for bowlers. Use object-oriented development to create a Bowling application that simulates a simplified game of bowling. The Bowling application and its objects should:

- Allow a bowler to bowl ten frames. Each frame consists of two throws, unless a strike is thrown.
- Award 20 points to the bowler when all ten pins are knocked over on the first throw of a frame.
- Award 15 points to the bowler when all ten pins are knocked over within the two throws of a frame.
- Award one point for each pin knocked over in the two throws of a frame when all ten pins are not knocked over.
- If there is more than one bowler in a game, then the bowlers take turns until each has bowled ten frames.
- Use a random number generator to determine how many pins a bowler has knocked over with each throw.
- Display an updated score after each frame.

## Exercise 8

## Adder

The Adder game prompts a player for the answer to an addition problem. The Adder game creates a problem from two randomly selected integers between 0 and 20. Adder allows the player three tries to enter a correct answer. If the correct answer is entered on the first try, the player is awarded 5 points. If the correct answer is entered on the second try, 3 points are awarded. The correct answer on the third try earns 1 point. If after three tries, the correct answer is still not entered, the player receives no points and the correct answer is displayed. The game continues until 999 is entered as an answer. At the end of the game, Adder displays the player's score. Application output should look similar to:

```
20 + 5 = 25
20 + 2 = 20
Wrong answer. Enter another answer: 22
3 + 6 = 5
Wrong answer. Enter another answer: 4
Wrong answer. Enter another answer: 7
5 + 12 = 17
14 + 18 = 999
Your score is: 13
```

# Chapter 9

## Inheritance and Polymorphism

Object-oriented programming is based on a paradigm in which objects are used to model a specification. Objects are created from classes, which provide encapsulation. Inheritance extends a class and provides a means of polymorphism. This chapter discusses inheritance and polymorphism. Abstract classes and interfaces are also discussed.

### Extending a Class

Often times there is an existing class that provides a basis for an object that models a specification. However, the existing class may need additional methods or different implementations of existing methods to more closely represent the object for the model. For example, consider a disk, which has circular shape. It is similar to a circle. However, a disk is three-dimensional and also has a thickness. Rather than create a whole new class to represent a disk, a class named Disk could extend the Circle class.

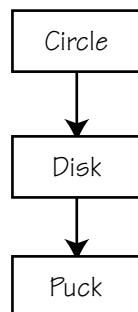
*inheritance*

*is-a relationship*

**TIP** The Object class is the superclass of all other classes.

Making one class an extension of another involves inheritance. *Inheritance* allows a class to define a specialized type of an already existing class. In this case, a disk is a solid circle with a thickness. Classes that are derived from existing classes demonstrate an *is-a relationship*. A class “is a” type of another class. In this case, a disk is a circle with a thickness.

A class can have many levels of inheritance. For example, consider the following class hierarchy:



The Puck class inherits the Disk class, which inherits the Circle class. The Circle class is the superclass of Disk. Disk is the subclass of Circle and the superclass of Puck. Puck is the subclass of Disk.

# Implementing a Subclass

**extends** A class that inherits another class includes the keyword `extends` in the class declaration and takes the form:

```
public class <name> extends <class_name> {
 <class definition>
}
```

**base class** Designing a subclass requires selecting the superclass, or *base class*, and then defining any additional variable and method members for the subclass. In many cases, existing methods in the base class will also be overridden by new definitions in the subclass, also called the *derived class*. For example, the Disk class design appears similar to:

```
Disk inherits Circle

variable: thickness

methods:
 setThickness – changes the thickness.
 getThickness – returns the thickness.
 volume – returns the volume of the disk.
 equals – overrides the equals() method in Circle.
 toString – overrides the toString() method in Circle.
```

The Disk class implementation, based on the design above, is:

```
/**
 * Disk class.
 */
public class Disk extends Circle {
 private double thickness;

 /**
 * constructor
 * pre: none
 * post: A Disk object has been created with radius r
 * and thickness t.
 */
 public Disk(double r, double t) {
 super(r);
 thickness = t;
 }

 /**
 * Changes the thickness of the disk.
 * pre: none
 * post: Thickness has been changed.
 */
 public void setThickness(double newThickness) {
 thickness = newThickness;
 }
```

```

 /**
 * Returns the thickness of the disk.
 * pre: none
 * post: The thickness of the disk has been returned.
 */
 public double getThickness() {
 return(thickness);
 }

 /**
 * Returns the volume of the disk.
 * pre: none
 * post: The volume of the disk has been returned.
 */
 public double volume() {
 double v;

 v = super.area() * thickness;
 return(v);
 }

 /**
 * Determines if the object is equal to another
 * Disk object.
 * pre: d is a Disk object.
 * post: true has been returned if objects have the same
 * radii and thickness. false has been returned otherwise.
 */
 public boolean equals(Object d) {
 Disk testObj = (Disk)d;

 if (testObj.getRadius() == super.getRadius()
 && testObj.getThickness() == thickness) {
 return(true);
 } else {
 return(false);
 }
 }

 /**
 * Returns a String that represents the Disk object.
 * pre: none
 * post: A string representing the Disk object has
 * been returned.
 */
 public String toString() {
 String diskString;

 diskString = "The disk has radius " + super.getRadius()
 + " and thickness " + thickness + ".";
 return(diskString);
 }
}

```

**TIP** The equals() and toString() methods override the methods by the same name in the Circle class.

### super visibility

In a subclass, the keyword `super` is used to access methods of the base class. For example, the statement `super(r)` calls the constructor of the superclass, Circle, and passes an argument for setting the radius value. Members that are declared `private` are not accessible to derived classes. Therefore, accessor methods are used to get inherited member variable values. For example, the equals() method in the Disk class calls `getRadius()`.

Inherited methods are called directly from an object, just as any method of the class is called. Whether a method is original to the Disk class or inherited from the Circle class is transparent to client code, as demonstrated in the TestDisk application:

```
public class TestDisk {

 public static void main(String[] args) {
 Disk saucer = new Disk(10, 0.02);

 System.out.println("Disk radius: " + saucer.getRadius());
 System.out.println("Disk surface area: " + saucer.area());
 System.out.println("Disk volume: " + saucer.volume());

 Disk plate1 = new Disk(12, 0.05);
 Disk plate2 = new Disk(12, 0.07);
 if (plate1.equals(plate2)) {
 System.out.println("Objects are equal.");
 } else {
 System.out.println("Objects are not equal.");
 }
 System.out.println(plate1);
 System.out.println(plate2);
 }
}
```

The TestDisk application displays the following output:

```
Disk radius: 10.0
Disk surface area: 314.0
Disk volume: 6.28
Objects are not equal.
The disk has radius 12.0 and thickness 0.05.
The disk has radius 12.0 and thickness 0.07.
```

## Review: Puck – part 1 of 2

Create a Puck class that inherits the Disk class. The Puck class should include member variables `weight`, `standard`, and `youth`. The `standard` and `youth` variables should be boolean variables that are set to either `true` or `false` depending on the weight of the puck. A standard puck weighs between 5 and 5.5 ounces. A youth puck weighs between 4 and 4.5 ounces. Official hockey pucks, regardless of weight, are one inch-thick with a three-inch diameter. The Puck class should also contain member methods `getWeight()`, `getDivision()`, which returns a string stating whether the puck is standard or youth, and `equals()` and `toString()`, which override the same methods in the Disk class. The Puck constructor should require an argument for weight. Be sure that the constructor initializes other variables to appropriate values as necessary.

Create a Hockey application that tests the Puck class.

# Polymorphism

*Polymorphism* is an OOP property in which objects have the ability to assume different types. In object-oriented programming, polymorphism is based on inheritance. Because a subclass is derived from a superclass, a superclass object can reference an object of the subclass. For example, the following statements are valid because Disk inherits Circle:

```
Circle wafer;
Disk cookie = new Disk(2, 0.5);
wafer = cookie; //wafer now references cookie
```

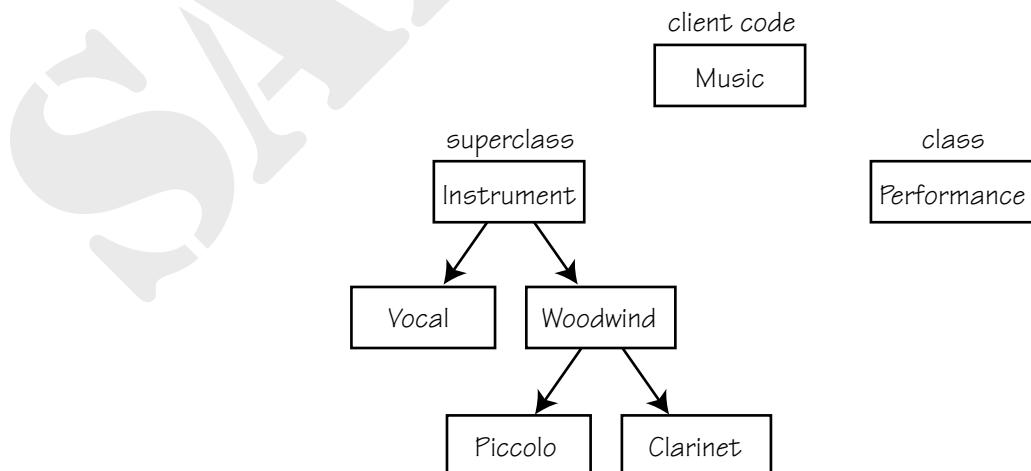
The `wafer` object, declared a Circle, is polymorphic, as demonstrated in the statement `wafer = cookie` where `wafer` assumes the form of `cookie`, a Disk object.

Polymorphism is further demonstrated when the referenced object determines which method to execute. This is possible when a subclass overrides a superclass method. In this case, the Disk class has overridden the `equals()` and `toString()` methods. Because of this, the following statement executes the Disk `toString()` method even though `wafer` was declared a Circle object:

```
/* displays: The disk has radius 2.0 and thickness 0.5. */
System.out.println(wafer);
```

To further demonstrate polymorphism, the Music application will be developed in this section. The Music application allows the user to assemble a small band. The user can assign a band member either vocals (voice) or a woodwind instrument (piccolo or clarinet). The user can then select to hear either a solo, duet, or trio performance from this band.

The Instrument class, its subclasses, and the Performance class are used to model the objects for the Music application. The diagram below illustrates the client code and classes for the Music application. Note the hierarchy of the Instrument class and its subclasses:



The Music client code is shown below:

```
/*
 * Music.java
 */
import java.util.Scanner;

public class Music {

 /* Returns a selected instrument.
 * pre: none
 * post: An instrument object has been returned.
 */
 public static Instrument assignInstrument() {
 String instrumentChoice;
 Scanner input = new Scanner(System.in);

 System.out.println("Select an instrument for the
 band member. ");
 System.out.print("Vocals, Piccolo, or Clarinet: ");
 instrumentChoice = input.nextLine();
 System.out.print("Enter the band member's name: ");
 name = input.nextLine();
 if (instrumentChoice.equalsIgnoreCase("V")) {
 return(new Vocal(name));
 } else if (instrumentChoice.equalsIgnoreCase("P")) {
 return(new Piccolo(name));
 } else { //default to clarinet
 return(new Clarinet(name));
 }
 }

 public static void main(String[] args) {
 Performance band;
 Instrument bandMember1, bandMember2, bandMember3;
 Scanner input = new Scanner(System.in);
 String performanceChoice;

 /* assign instruments */
 bandMember1 = assignInstrument();
 bandMember2 = assignInstrument();
 bandMember3 = assignInstrument();
 System.out.println(bandMember1 + " " + bandMember2 + " "
 + bandMember3 + "\n");

 System.out.print("Would you like to hear a Solo, a Duet,
 a Trio, or Leave? ");
 performanceChoice = input.nextLine();
 while (!performanceChoice.equalsIgnoreCase("L")) {
 if (performanceChoice.equalsIgnoreCase("S")) {
 band = new Performance(bandMember1);
 } else if (performanceChoice.equalsIgnoreCase("D")) {
 band = new Performance(bandMember1, bandMember2);
 } else { //default to trio
 band = new Performance(bandMember1, bandMember2,
 bandMember3);
 }
 band.begin();

 System.out.print("\nWould you like to hear a Solo,
 a Duet, a Trio, or Leave? ");
 performanceChoice = input.nextLine();
 }
 }
}
```

The assignInstrument() method declares an Instrument return type, but the individual `return` statements return Vocal, Piccolo, and Clarinet types. The Instrument object returned by the method is polymorphic, changing to whichever subclass is actually returned.

The Music application produces output similar to:

```
Select an instrument for the band member.
Vocals, Piccolo, or Clarinet: c
Enter the band member's name: Anthony
Select an instrument for the band member.
Vocals, Piccolo, or Clarinet: v
Enter the band member's name: Lyn
Select an instrument for the band member.
Vocals, Piccolo, or Clarinet: p
Enter the band member's name: Dana
Anthony plays squawk. Lyn sings LaLaLa. Dana plays peep.
```

```
Would you like to hear a Solo, a Duet, a Trio, or Leave? s
squawk
```

```
Would you like to hear a Solo, a Duet, a Trio, or Leave? d
squawkLaLaLa
```

```
Would you like to hear a Solo, a Duet, a Trio, or Leave? t
squawkLaLaLapeep
```

```
Would you like to hear a Solo, a Duet, a Trio, or Leave? l
```

The Music application allows the user numerous combinations for selecting a band and hearing performances. The code for such an application would be more complicated and less flexible without the object-oriented principles of inheritance and polymorphism. Music is versatile because it takes advantage of inheritance and polymorphism.

The documentation for the Instrument, Vocal, Woodwind, Piccolo, and Clarinet classes is below. Note that the `makeSound()` method in the Instrument class is a method that must be implemented (written) in a subclass. This is discussed further in the next section. The code for the classes is also shown in the next section where abstract classes are discussed.

#### Class Instrument

##### Constructor/Methods

`Instrument(String name)`

creates an instrument object with musician name.

`getMusician()` returns a string that is the musician's name.

`makeSound()` an abstract method that should return a String representing the instrument's sound.

### Class Vocal (inherits Instrument)

#### Constructor/Methods

Vocal(String name)

creates a singer object with singer name.

makeSound() returns the String LaLaLa.

toString() returns a String that represents the singer.

### Class Woodwind (inherits Instrument)

#### Constructor/Method

Woodwind(String name)

creates a woodwind instrument object with musician name.

makeSound() returns the String toot.

### Class Piccolo (inherits Woodwind)

#### Constructor/Methods

Piccolo(String name)

creates a piccoloist object with musician name.

makeSound() returns the String peep.

toString() returns a String that represents the object.

### Class Clarinet (inherits Woodwind)

#### Constructor/Methods

Clarinet(String name)

creates a clarinetist object with musician name.

makeSound() returns the String squawk.

toString() returns a String that represents the object.

The Performance class creates an arrangement of Instrument objects. The constructors require Instrument arguments, but polymorphism enables objects of Instructor subclasses to be passed:

```
/**
 * Performance class.
 */
public class Performance {
 private String arrangement;
 private Instrument solo;
 private Instrument duet_1, duet_2;
 private Instrument trio_1, trio_2, trio_3;

 /**
 * constructor
 * pre: none
 * post: A soloist has been selected.
 */
 public Performance(Instrument s) {
 solo = s;
 arrangement = solo.makeSound();
 }
}
```

```

 /**
 * constructor
 * pre: none
 * post: The members of a duet have been selected.
 */
 public Performance(Instrument d1, Instrument d2) {
 duet_1 = d1;
 duet_2 = d2;
 arrangement = duet_1.makeSound() + duet_2.makeSound();
 }

 /**
 * constructor
 * pre: none
 * post: The members of a trio have been selected.
 */
 public Performance(Instrument t1, Instrument t2,
 Instrument t3) {
 trio_1 = t1;
 trio_2 = t2;
 trio_3 = t3;
 arrangement = trio_1.makeSound() + trio_2.makeSound()
 + trio_3.makeSound();
 }

 /**
 * Begins the performance.
 * pre: none
 * post: The performance has been played.
 */
 public void begin() {
 System.out.println(arrangement);
 }

 /**
 * Returns a String that represents the performers.
 * pre: none
 * post: A string representing the performers has
 * been returned.
 */
 public String toString() {
 String program = "The performance includes ";
 program += arrangement;
 return(program);
 }
}

```

## Review: Music – part 1 of 2

Modify the Music application to allow the user to select a quartet (four band members) in addition to the other performances. Changes to the Performance class will also be required to provide the option of creating a quartet.

# Abstract Classes

An *abstract class* models an abstract concept. For example, a musical instrument is an abstract concept. An instrument is something that can be played, but there is no such thing as an “instrument” instrument. There are however, flutes, piccolos, drums, and cymbals.

Abstract classes cannot be instantiated because they should not represent objects. They instead describe the more general details and actions of a type of object. For example, the Instrument class describes the very basics of an instrument—it can make a sound. The Woodwind class is also an abstract class because it describes a group of instruments. It includes a general sound that woodwind instruments make.

## abstract

Abstract classes are declared with the keyword `abstract` in the class declaration. They are intended to be inherited. The public members of the abstract class are visible to derived objects. However, an abstract class can also contain an abstract method. An *abstract method* is declared with the keyword `abstract` and contains a method declaration, but no body. The abstract class must be implemented in its subclass.

## abstract method

The Instrument class is an abstract class with an abstract method. The `makeSound()` method must be implemented in an Instrument subclass:

```
/**
 * Instrument class.
 */
abstract class Instrument {
 String musician;

 /**
 * constructor
 * pre: none
 * post: A musician has been assigned to the instrument.
 */
 public Instrument(String name) {
 musician = name;
 }

 /**
 * Returns the name of the musician
 * pre: none
 * post: The name of the musician playing the instrument
 * has been returned.
 */
 public String getMusician() {
 return(musician);
 }

 /**
 * Should return the sound of the instrument.
 * pre: none
 * post: The sound made by the instrument is returned.
 */
 abstract String makeSound();
}
```

The Vocal class is a subclass of Instrument. It provides the body for the `makeSound()` method:

```

/**
 * Vocal class.
 */
public class Vocal extends Instrument {

 /**
 * constructor
 * pre: none
 * post: A singer has been created.
 */
 public Vocal(String singerName) {
 super(singerName);
 }

 /**
 * Returns the sound of the instrument.
 * pre: none
 * post: The sound made by the singer.
 */
 public String makeSound() {
 return("LaLaLa");
 }

 /**
 * Returns a String that represents the instrument.
 * pre: none
 * post: A string representing the singer.
 */
 public String toString() {
 return(super.getMusician() + " sings " + makeSound() + ".");
 }
}

```

The Woodwind class is also an Instrument subclass. It too implements the makeSound() method. However, Woodwind describes a group of instruments so it has also been declared abstract:

```

/**
 * Woodwind class.
 */
abstract class Woodwind extends Instrument {

 /**
 * constructor
 * pre: none
 * post: A woodwind instrument has been created.
 */
 public Woodwind(String player) {
 super(player);
 }

 /**
 * Returns the sound of the instrument.
 * pre: none
 * post: The sound made by the instrument is returned.
 */
 public String makeSound() {
 return("toot");
 }
}

```

The Piccolo class is a subclass of Woodwind. It overrides the makeSound() method:

```
/**
 * Piccolo class.
 */
public class Piccolo extends Woodwind {

 /**
 * constructor
 * pre: none
 * post: A piccolo has been created.
 */
 public Piccolo(String piccoloist) {
 super(piccoloist);
 }

 /**
 * Returns the sound of the instrument.
 * pre: none
 * post: The sound made by the instrument is returned.
 */
 public String makeSound() {
 return("peep");
 }

 /**
 * Returns a String that represents the instrument.
 * pre: none
 * post: A string representing the instrument has
 * been returned.
 */
 public String toString() {
 return(super.getMusician() + " plays " + makeSound() + ".");
 }
}
```

The Clarinet class is also a Woodwind subclass. It too overrides the makeSound() method:

```
/**
 * Clarinet class.
 */
public class Clarinet extends Woodwind {

 /**
 * constructor
 * pre: none
 * post: A clarinet has been created.
 */
 public Clarinet(String clarinetist) {
 super(clarinetist);
 }

 /**
 * Returns the sound of the instrument.
 * pre: none
 * post: The sound made by the instrument is returned.
 */
 public String makeSound() {
 return("squawk");
 }
}
```

```

 /**
 * Returns a String that represents the instrument.
 * pre: none
 * post: A string representing the instrument has
 * been returned.
 */
 public String toString() {
 return(super.getMusician() + " plays " + makeSound() + ".");
 }
}

```

Through inheritance and abstraction, a hierarchy of classes can be created that begin with a general abstraction and lead to a specific object.

## Review: Music – part 2 of 2

Modify the Music application to allow the user to select a cymbal or drum in addition to the other instruments for the band members. The Music application changes will require that Percussion, Cymbal, and Drum classes be created. The Percussion class should be an abstract class that inherits the Instrument class. The Cymbal and Drum classes should inherit the Percussion class.

## Interfaces

An *interface* is a class with method declarations that have no implementations. Although an interface may seem similar to an abstract class, it is very different. An interface cannot be inherited. It may only be implemented in a class. An interface can add behavior to a class, but it does not provide a hierarchy for the class.

An interface takes the form:

```

<access_level> interface <name> {
 <return_type> <method_name> (<method_param>);
 ...additional methods
}

```

The methods defined in an interface are by default public and abstract. Therefore, the methods in an interface are only declarations followed by a semicolon.

### Comparable interface

The Comparable interface is part of the java.lang package. It contains one method:

Interface Comparable (java.lang.Comparable)

Method

`compareTo(Object obj)`

returns 0 when `obj` is the same as the object, a negative integer is returned when `obj` is less than the object, and a positive integer is returned when `obj` is greater than the object.

When an interface is implemented in a class, the class must implement each method defined in the interface. In this case, the Comparable interface contains just one method. The Circle class shown on the next page has been modified to implement the Comparable interface.

```

/**
 * Circle class.
 */
public class Circle implements Comparable {
 private static final double PI = 3.14;
 private double radius;

 /**
 * constructor
 * pre: none
 * post: A Circle object created. Radius initialized to 1.
 */
 public Circle() {
 radius = 1; //default radius
 }

```

*...getRadius(), setRadius(), and other Circle class methods*

```

/**
 * Determines if object c is smaller, the same,
 * or larger than this Circle object.
 * pre: c is a Circle object
 * post: -1 has been returned if c is larger than
 * this Circle, 0 has been returned if they are the
 * same size, and 1 has been returned if c is smaller
 * than this Circle.
 */
public int compareTo(Object c) {
 Circle testCircle = (Circle)c;

 if (radius < testCircle.getRadius()) {
 return(-1);
 } else if (radius == testCircle.getRadius()) {
 return(0);
 } else {
 return(1);
 }
}

```

The TestCircle client code tests the compareTo() method:

```

/**
 * The Circle class is tested.
 */
public class TestCircle {

 public static void main(String[] args) {
 Circle spot1 = new Circle(3);
 Circle spot2 = new Circle(4);
 if (spot1.compareTo(spot2) == 0) {
 System.out.println("Objects are equal.");
 } else if (spot1.compareTo(spot2) < 0) {
 System.out.println("spot1 is smaller than spot2.");
 } else {
 System.out.println("spot1 is larger than spot2.");
 }
 System.out.println(spot1);
 System.out.println(spot2);
 }
}

```

The TestCircle application produces the output:

```
spot1 is smaller than spot2.
Circle has radius 3.0
Circle has radius 4.0
```

### *multiple interfaces*

A class can implement multiple interfaces. When more than one interface is implemented, the interface names are separated by commas in the class declaration.

## Review: Disk

Modify the Disk class to implement the Comparable interface. Two disks are equal when they have the same thickness and same radius. Modify the existing client code to test the new method.

## Review: Puck – part 2 of 2

Modify the Puck class to implement the Comparable interface. Two pucks are the equal when they have the same weight. Modify the existing client code to test the new method.

## Review: Rectangle – part 4 of 4

Modify the Rectangle class to implement the Comparable interface. Two rectangles are the equal when they have the same width and height. Modify the existing client code to test the new method.

## Review: Rectangle – part 4 of 5

Create an interface named ComparableArea that contains one method named compareToArea(). This method should return 0 when the object has the same area as another object, -1 should be returned when the object has an area less than another object, and 1 returned otherwise.

Modify the Rectangle class to implement the ComparableArea interface as well as the Comparable interface implemented in the previous review. Modify the existing client code to test the new method.

## Chapter 9 Case Study

In this case study, a sales center application will be created. The sales center has three employees, which include a manager and two associates. The manager earns a salary and the associates are paid by the hour. The owner of the sales center wants a computer application to display employee information and calculate payroll.

## SalesCenter Specification

The SalesCenter application stores information about three employees. There is one manager (Diego Martin, salary \$55,000), and two associates (Kylie Walter earning \$18.50 per hour and Michael Rose earning \$16.75 per hour). SalesCenter should be able to display the name and title for a specified employee. Additionally, the SalesCenter application should calculate and display the pay for a specified employee based on the pay argument entered by the user. The pay argument should correlate to hours worked if the pay for an associate is to be calculated. The pay argument for a manager should correlate to the number of weeks the manager is to be paid for.

The SalesCenter interface should provide a menu of options. Depending on the option selected, additional input may be needed. The SalesCenter output sketch:

```
Employee\Pay\Quit
Enter choice: E
Enter employee number (1, 2, or 3): 2 Kylie Walter, associate
```

```
Employee\Pay\Quit
Enter choice: P
Enter employee number (1, 2, or 3): 2
Enter the hours for associate or pay period for manager: 40
Kylie Walter, associate
$740.00
```

```
Employee\Pay\Quit
Enter choice: Q
```

The SalesCenter algorithm:

1. Display a menu of options.
2. Prompt the user for a menu choice.
3. If the user has not selected to quit, prompt the user to specify employee 1, 2, or 3.
4. Perform the action requested by the user.
5. Repeat steps 1 through 4 until the user has selected the option to quit.

## SalesCenter Code Design

The SalesCenter application can be modeled with objects for a manager and two associates. The manager and associate objects are both employee objects. Therefore, an Employee abstract class should be used for subclasses Manager and Associate. The Employee class should define an employee's first and last name and include an abstract class for calculating pay. A manager's pay is based on a pay period specified in weeks. Associates are paid by the hour. The `abstract pay()` method in Employee will have different implementations in Manager and Associate.

The SalesCenter class designs are:

Employee

variables: `firstName, lastName`

methods:

`pay` – abstract class. Should return an employee's pay for a specified period.

`toString` – returns a string with employee first and last names.

Manager extends Employee

variable: `yearlySalary`

methods:

`getSalary` – returns the yearly salary.

`pay` – returns amount earned based on the yearly salary and the specified period. Requires a parameter for the weeks in the pay period.

`toString` – returns a string with employee name and title.

Associate extends Employee

variable: `hourlyPayRate`

methods:

`getRate` – returns the hourly pay rate.

`pay` – returns amount earned based on the hourly pay rate and the specified hours. Requires a parameter for hours worked.

`toString` – returns a string with employee name and title.

Based on the algorithm and the class designs, the SalesCenter code design will include a loop. The pseudocode for the SalesCenter client code follows:

```
import java.util.Scanner;
import java.text.NumberFormat;

public class SalesCenter {

 payEmployee(emp, payArg) {
 System.out.println(emp);
 pay = emp.pay(payArg);
 System.out.println(pay);
 }

 public static void main(String[] args) {
 Manager empl = new Manager("Diego", "Martin", 55000);
 Associate emp2 = new Associate("Kylie", "Walter", 18.50);
 Associate emp3 = new Associate("Michael", "Rose", 16.75);
 Employee emp = empl; //default employee choice

 /* display menu of choices */
 do {
 prompt user for employee/pay/quit
 get user choice;

 if (not quit) {
 prompt user for employee number 1, 2, or 3
 get empNum
 switch (empNum) {
 case 1: emp = empl; break;
 case 2: emp = emp2; break;
 case 3: emp = emp3; break;
 }
 if (choice == employee) {
 display employee name and title;
 } else if (choice == pay) {
 prompt user for hours or pay period;
 payEmployee(emp, payArg);
 }
 }
 } while (not quit);
 }
}
```

### SalesCenter Implementation

The SalesCenter implementation involves creating four files. Three files are the classes and one file is the client code.

The Employee class is implemented below:

```
/*
 * Employee class.
 */
abstract class Employee {
 String firstName, lastName;

 /**
 * constructor
 * pre: none
 * post: An employee has been created.
 */
 public Employee(String fName, String lName) {
 firstName = fName;
 lastName = lName;
 }

 /**
 * Returns the employee name.
 * pre: none
 * post: The employee name has been returned.
 */
 public String toString() {
 return(firstName + " " + lastName);
 }

 /**
 * Returns the employee pay.
 * pre: none
 * post: The employee pay has been returned.
 */
 abstract double pay(double period);
}
```

The Manager class is implemented below:

```
/*
 * Manager class.
 */
class Manager extends Employee {
 double yearlySalary;

 /**
 * constructor
 * pre: none
 * post: A manager has been created.
 */
 public Manager(String fName, String lName, double sal) {
 super(fName, lName);
 yearlySalary = sal;
 }

 /**
 * Returns the manager salary.
 * pre: none
 * post: The manager salary has been returned.
 */
 public double getSalary() {
 return(yearlySalary);
 }
}
```

```

 /**
 * Returns the manager pay for a specified period.
 * pre: none
 * post: The manager pay for the specified period
 * has been returned.
 */
 public double pay(double weeks) {
 double payEarned;

 payEarned = (yearlySalary / 52) * weeks;
 return(payEarned);
 }

 /**
 * Returns the employee name and title.
 * pre: none
 * post: The employee name and title has been returned.
 */
 public String toString() {
 return(super.toString() + ", manager");
 }
}

```

The Associate class is implemented below:

```

 /**
 * Associate class.
 */
 class Associate extends Employee {
 double hourlyPayRate;

 /**
 * constructor
 * pre: none
 * post: An associate has been created.
 */
 public Associate(String fName, String lName, double rate) {
 super(fName, lName);
 hourlyPayRate = rate;
 }

 /**
 * Returns the associate pay rate.
 * pre: none
 * post: The associate pay rate has been returned.
 */
 public double getRate() {
 return(hourlyPayRate);
 }

 /**
 * Returns the associate pay for the hours worked.
 * pre: none
 * post: The associate pay for the hours worked
 * has been returned.
 */
 public double pay(double hours) {
 double payEarned;

 payEarned = hourlyPayRate * hours;
 return(payEarned);
 }
 }

```

```

 /**
 * Returns the employee name and title.
 * pre: none
 * post: The employee name and title has been returned.
 */
 public String toString() {
 return(super.toString() + ", associate");
 }
}

```

The SalesCenter client code is implemented below:

```

import java.util.Scanner;
import java.text.NumberFormat;

public class SalesCenter {

 /**
 * Displays employee name and pay.
 * pre: none
 * post: Employee name and pay has been displayed
 */
 public static void payEmployee(Employee emp, double payArg) {
 NumberFormat money = NumberFormat.getCurrencyInstance();
 double pay;

 System.out.println(emp);
 pay = emp.pay(payArg);
 System.out.println(money.format(pay));
 }

 public static void main(String[] args) {
 Manager emp1 = new Manager("Diego", "Martin", 55000);
 Associate emp2 = new Associate("Kylie", "Walter", 18.50);
 Associate emp3 = new Associate("Michael", "Rose", 16.75);
 Scanner input = new Scanner(System.in);
 String action;
 int empNum;
 double payArg;
 Employee emp = emp1; //set to default emp1

 do {
 System.out.println("\nEmployee\\Pay\\Quit");
 System.out.print("Enter choice: ");
 action = input.next();

 if (!action.equalsIgnoreCase("Q")) {
 System.out.print("Enter employee number (1, 2, or 3):");
 empNum = input.nextInt();
 switch (empNum) {
 case 1: emp = emp1; break;
 case 2: emp = emp2; break;
 case 3: emp = emp3; break;
 }
 if (action.equalsIgnoreCase("E")) {
 System.out.println(emp);
 } else if (action.equalsIgnoreCase("P")) {
 System.out.print("Enter the hours for associate or
 pay period for manager: ");
 payArg = input.nextDouble();
 payEmployee(emp, payArg);
 }
 }
 } while (!action.equalsIgnoreCase("Q"));
 }
}

```

The SalesCenter application generates output similar to:

```
Employee\Pay\Quit
Enter choice: e
Enter employee number (1, 2, or 3):1
Diego Martin, manager

Employee\Pay\Quit
Enter choice: p
Enter employee number (1, 2, or 3):1
Enter the hours for associate or pay period for manager: 2
Diego Martin, manager
$2,115.38

Employee\Pay\Quit
Enter choice: q
```

### SalesCenter Testing and Debugging

Client code should first be written to test each class. Testing should be done for the client code.

## Review: SalesCenter

Modify the SalesCenter application to compensate associates when they have worked more than 40 hours. Associates should be paid their hourly wage when 40 or fewer hours are worked. However, associates earn time and a half for hours over 40. For example, an associate paid \$10 per hour will earn \$300 for 30 hours of work. However, an associate working 42 hours will earn \$400 + \$30, or \$430. The overtime pay is calculated as (hours over 40) \* (1.5 \* base hourly rate).

## Chapter Summary

This chapter discussed inheritance and polymorphism, two key aspects of object-oriented programming. Inheritance allows classes to be derived from existing classes. By extending an existing class, there is less development and debugging necessary. A class derived from an existing class demonstrates an is-a relationship.

A superclass is also called a base class, and a subclass is called a derived class. The keyword `extends` is used to create a derived class from a base class. The keyword `super` is used to access members of a base class from the derived class.

Polymorphism is the ability of an object to assume different types. In OOP, polymorphism is based on inheritance. An object can assume the type of any of its subclasses.

Abstract classes model abstract concepts. They cannot be instantiated because they should not represent objects. An abstract class is intended to be inherited.

Abstract classes may or may not contain abstract methods. An abstract method is a method declaration with no implementation. If a class contains one or more abstract methods, it must be declared abstract. Abstract methods must be implemented in a class that inherits the abstract class.

An interface is a class that contains only abstract methods. An interface can be implemented by a class, but it is not inherited. A class that implements an interface must implement each method in the interface. The Comparable interface is part of the java.lang package and is used to add a compareTo() method to classes that implement the interface.

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## Vocabulary

**Abstract class** A class that models an abstract concept. A class that contains one or more abstract methods must be declared abstract.

**Abstract method** A method that has been declared, but not implemented. Abstract methods appear in abstract classes. They are implemented in a subclass that inherits the abstract class.

**Base class** A superclass.

**Derived class** A subclass.

**Inheritance** The OOP property in which a class can define a specialized type of an already existing class.

**Interface** A class with abstract methods. An interface cannot be inherited, but it can be implemented by any number of classes.

**Is-a relationship** The relationship demonstrated by a class derived from an existing class.

**Polymorphism** The OOP property in which objects have the ability to assume different types.

## Java

**abstract** The keyword used for declaring a class or a method as abstract.

**Comparable** A java.lang interface with the compareTo() method that can be implemented in classes to provide a means for an object to be compared to another object of the same type.

**extends** The keyword used in a class declaration to inherit another class.

**interface** The keyword used in a class declaration to declare it an interface.

**super** The keyword used to call a superclass constructor or method.

## Critical Thinking

1. Explain the difference between a has-a and is-a relationship among classes.
2. If a base class has a public method go() and a derived class has a public method stop(), which methods will be available to an object of the derived class?
3. Compare and contrast implementing an abstract method to overriding a method.
4. Compare and contrast an abstract class to an interface.
5. List the method(s) contained in the Comparable interface.
6. Use the following classes to answer the questions below:

```
interface Wo {
 public int doThat();
}

public class Bo {
 private int x;

 public Bo(int z) {
 x = z;
 }

 public int doThis() {
 return(2);
 }

 public int doNow() {
 return(15);
 }
}

public class Roo extends Bo implements Wo {
 public Roo {
 super(1);
 }

 public int doThis() {
 return(10);
 }

 private int doThat() {
 return(20);
 }
}
```

- a) What type of method is doThat() in Wo?
- b) What is Wo?
- c) Why is doThat() implemented in Roo?
- d) List the methods available to a Roo object.

- e) How does the implementation of doThis() in Roo affect the implementation of doThis() in Bo?
- f) What action does the statement `super(1)` in Roo perform?
- g) Can the doThis() method in Bo be called from a Roo object? If so, how?
- h) Can a method in Roo call the doThis() method in Bo? If so, how?

### True/False

7. Determine if each of the following are true or false. If false, explain why.
  - a) Inheritance allows a class to define a specialized type of an already existing class.
  - b) Classes that are derived from existing classes demonstrate a has-a relationship.
  - c) A class can have only one level of inheritance.
  - d) A class that inherits another class includes the keyword `inheritance` in the class declaration.
  - e) When implementing a subclass, existing methods in the base class can be overridden.
  - f) Members of a base class that are declared private are accessible to derived classes.
  - g) Inherited methods are called directly from an object.
  - h) Polymorphism is an OOP property in which objects have the ability to assume different types.
  - i) Abstract classes can be instantiated.
  - j) An abstract class must be implemented in its subclass.
  - k) An abstract method contains a method declaration and a body.
  - l) Inheritance and abstraction allow a hierarchy of classes to be created.
  - m) An interface can be inherited.
  - n) An interface can add behavior to a class.
  - o) The methods defined in an interface are private by default.
  - p) The Comparable interface contains three methods.

## Exercises

### Exercise 1 ————— UEmployee, Faculty, Staff

Create a UEmployee class that contains member variables for the university employee name and salary. The UEmployee class should contain member methods for returning the employee name and salary. Create Faculty and Staff classes that inherit the UEmployee class. The Faculty class should include members for storing and returning the department name. The Staff class should include members for storing and returning the job title.

### Exercise 2 ————— Account, PersonalAcct, BusinessAcct

Create PersonalAcct and BusinessAcct classes that inherit the Account class presented in Chapter 8. A personal account requires a minimum balance of \$100. If the balance falls below this amount, then \$2.00 is charged (withdrawn) to the account. A business account requires a minimum balance of \$500, otherwise the account is charged \$10. Create client code to test the classes.

### Exercise 3 ————— Vehicle, Car, Truck, Minivan

Create a Vehicle class that is an abstract class defining the general details and actions associated with a vehicle. Create Car, Truck, and Minivan classes that inherit the Vehicle class. The Car, Truck, and Minivan classes should include additional members specific to the type of vehicle being represented. Create client code to test the classes.

# Chapter 10

## Arrays

**A**rrays are used to implement many different kinds of algorithms. This chapter explains how to create and use arrays. Searching arrays, two-dimensional arrays, and the `ArrayList` class are also discussed. Arrays of characters and Unicode are explained.

### Declaring Arrays

An *array* is a structure that can store many of the same kind of data together at once. For example, an array can store 20 integers, another array can store 50 doubles, and a third array can store 100 objects, such as `Strings`. Arrays are an important and useful programming concept because they allow a collection of related values to be stored together with a single descriptive name.

An array has a fixed length and can contain only as many data items as its length allows:

|        |         |       |      |      |
|--------|---------|-------|------|------|
| 0      | 1       | 2     | 3    | 4    |
| Kermit | Lucille | Sammy | Roxy | Myah |

friends

**array element  
index**

An array *element* is one of the data items in an array. For example, in the array of `Strings` above, `Roxy` is an element. Each element has an *index* value, with 0 being the index of the first item, 1 the index of the second item, and so on. In the array above, `Roxy` is the fourth element in the array and has the index value 3.

**declaring and allocating  
space for an array**

An array must be declared and then space allocated for the elements of the array. The statements for declaring an array and allocating space for its elements take the form:

```
<type>[] <name>; //declare array
<name> = new <type>[<num>]; //allocate space for elements
```

**TIP** The `[]` brackets are operators used for declaring and creating arrays and for accessing array elements.

The declaration includes the type followed by brackets (`[]`) to indicate an array. The array name can be any valid identifier. The `new` operator allocates space for the number of elements indicated in brackets. The statements on the next page declare an array and then prompt the user for the number of elements:

**TIP** An array is an immutable data structure, which cannot be changed from its original size.

```
Scanner input = new Scanner(System.in);
int numFriends;
String[] friends; //declare array

System.out.print("How many friends? ");
numFriends = input.nextInt();
friends = new String[numFriends]; //allocate space
```

If the size of the array is known when the application is written, then the array can be created and space allocated for elements in one statement, similar to:

```
String[] friends = new String[5]; //5 friends
```

### initial array values

When space has been allocated for the elements of an array, the array is initialized to the default values for that element type. For example, each element of an `int` array is automatically initialized to 0. An array of objects, such as a `String` array, contains `null` for each element.

### declaring and initializing

A third way to create an array is to initialize it in the declaration. Initializing an array means that a value is given for each element. In this case, the length of the array is determined by the number of elements between the curly braces:

```
String[] friends = {"Kermit", "Lucille", "Sammy", "Roxy", "Myah"};
```

## Using Arrays

### accessing an element

An array element is accessed by including its index in brackets after the array name. For example, the following statement displays the third element:

```
System.out.println(friends[2]); //displays Sammy
```

### changing an element

An array element is changed through assignment. For example, the assignment statement below changes the third element to "Sunshine":

```
friends[2] = "Sunshine";
```

### ArrayIndexOutOfBoundsException

A run-time error is generated when an invalid index is used. For example, the exception `ArrayIndexOutOfBoundsException` is thrown when the following statement tries to execute:

```
friends[5] = "Wilbur"; //ERROR! Generates an exception.
```

The `Array` structure includes the `length` attribute, which can be used at run time to determine the length of an array:

```
numElements = friends.length; //5
```

### traversing

A `for` statement is often used to access the elements of an array because the loop control variable can be used as the array index. Accessing each element of an array is called *traversing* an array. For example, the following statement displays each element of the `friends` array:

```
for (int i = 0; i < friends.length; i++) {
 System.out.println(friends[i]);
}
```

Note that the loop iterates from 0 to one less than the length of the array because `length` is a count of the elements, not the greatest index value.

**TIP** `length` is a property, not a method. Therefore, parentheses should not follow its name.

### for-each statement

**TIP** The `for-each` is new to Java 5 and requires JDK 5.

Java also provides a type of `for` loop just for traversing an array. Sometimes referred to as a `for-each` statement, the following statement displays each element in the array:

```
for (String element : friends) {
 System.out.println(element);
}
```

The statement above displays the names in the array one after the other. Using a `for-each` loop to traverse an array does not require a loop control variable. This type of `for` statement helps prevent the exception `ArrayIndexOutOfBoundsException`.

Although convenient at times, the modified `for` statement above cannot be used in situations where the array index value is needed. One example, is when the elements of an array are to be accessed in reverse order.

## Review: StudentRoster

Create a `StudentRoster` application that prompts the user for the number of students in the class and then prompts the user for each student's name and stores the names in an array. After all the names have been entered, the application should display the title "Student Roster" and then list the names in the array.

## Review: Squares

Create a `Squares` application that stores the square of an element's index in an integer array of 5 elements. For example, the third element, which has index 2, should store 4. The application should then display the value of each element in the array.

## Review: Reverse

Create a `Reverse` application that stores the number corresponding to the element's index in an integer array of 10 elements. For example, the second element, which has index 1, should store 1. The application should then display the title "Countdown" and then list numbers stored in the array in reverse order.

## Array Parameters

A method declaration can include array parameters. The array passed to a method can be either an entire array or an element of the array. The method below includes an array parameter. A second parameter, an `int` parameter, corresponds to an element of the array:

```
public static void tryChanging(int[] numbers, int aNum) {
 numbers[1] = 123;
 aNum = 456;
}
```

Note that the data type followed by brackets indicates an array parameter, similar to an array declaration.

The statements below call the `tryChanging()` method shown on the previous page:

```
int[] myNums = {5, 8, 3};
System.out.println(myNums[1] + " " + myNums[0]);
tryChanging(myNums, myNums[0]);
System.out.println(myNums[1] + " " + myNums[0]);
```

The statements produce the output:

```
8 5
123 5
```

An array is a reference data type similar to a class. Therefore, passing a whole array to a method passes the reference to the elements, allowing the method to access an element of the array and change its value. However, because the elements of the array are a primitive data type, passing a single element passes only the data stored, not a reference to the data location.

## Arrays with Meaningful Indexes

Many algorithms make use of the index value of an array element for simplifying the storage and retrieval of data. For example, a `testScores` array with 101 elements indexed from 0 to 100 could store a count of all the scores of 90 in the element with index 90, the count of scores 82 in element 82, and so on.

The `DiceRolls` application counts the frequency of dice roll outcomes. A roll is simulated by generating two random numbers between 1 and 6. The outcome of each roll is then used to increment the counter in the element at the index corresponding to the outcome. For example, if a 4 is rolled, then the value at index 4 is incremented:

```
import java.util.Scanner;
import java.util.Random;

public class DiceRolls {

 public static void main(String[] args) {
 int[] outcomes = new int[13];
 Scanner input = new Scanner(System.in);
 int numRolls;
 Random rand = new Random();
 int outcome;

 /* prompt user for number of rolls */
 System.out.print("How many rolls? ");
 numRolls = input.nextInt();

 /* roll dice and add to outcomes */
 for (int roll = 0; roll < numRolls; roll++) {
 outcome = (rand.nextInt(6) + 1) + (rand.nextInt(6) + 1);
 outcomes[outcome] += 1;
 }

 /* show counts of outcomes */
 for (int i = 2; i <= 12; i++) {
 System.out.println(i + ": " + outcomes[i]);
 }
 }
}
```

The DiceRolls application displays output similar to:

```
How many rolls? 1000
2: 25
3: 58
4: 75
5: 110
6: 150
7: 166
8: 161
9: 111
10: 74
11: 48
12: 22
```

In the DiceRolls application, the outcomes ranged from 2 through 12 making it possible to store counters at array indexes directly corresponding to the outcomes. However, this approach for a range of years 1900 through 2000 would require an array of 2001 elements with only the last 100 elements in use. For ranges such as these, the solution is to store counters at offset array indexes. For example, for an outcome of 1900, a counter at index 0 would be incremented. for an outcome of 1901, a counter at index 1 would be incremented, and so on.

#### *offset array indexes*

To determine the array size when offset array indexes will be used, subtract the low value from the high and add 1:

```
int[] counts;
counts = new int[HIGH - LOW + 1];
```

The following statement increments a counter stored at an offset index:

```
counts[value - LOW] += 1;
```

## Review: DiceRolls – part 1 of 2

Modify the DiceRolls application to roll three dice.

## Review: DiceRolls – part 2 of 2

The DiceRolls application is not written generically. The application has “hard-coded” data, including the maximum random number in the nextInt() method and the initial and final values for *i* in the show counts for loop. Modify the DiceRolls application to prompt the user for the number of sides on each die, the number of dice to be rolled, and the number of rolls to make. For example, a ten-sided die will show a number between a 1 and a 10 on a roll. Rolling three ten-sided dice has the possible outcomes of 3 through 30.

## Review: NumberCounts

Create a NumberCounts application that prompts the user for a number and then counts the occurrences of each digit in that number.

# Characters and Arrays

**TIP** The `char` data type was introduced in Chapter 4.

Although strings are comprised of characters, a `String` object cannot be manipulated as a set of characters. However, the string stored in a `String` object can be converted to a `char` array. Additionally, an individual character of the `String` object can be converted to a `char`. The `String` class methods for working with the characters in a string include:

**Class `String` (`java.lang.String`)**

**Method**

`charAt(int index)`

returns a `char` value that corresponds to the letter at position `index`.

`toCharArray()` returns the `String` object converted to a `char` array.

**`charAt()`**

**`toCharArray()`**

**`Unicode`**

**TIP** Refer to the appendix in this text for more Unicode symbols and their values.

The value returned by the `charAt()` method is a `char` data type. A `char` data type represents a single character, such as a letter or symbol. The `toCharArray()` method converts each character in the string to a `char` and then assigns it to the appropriate element in an existing `char` array.

Letters of every alphabet and symbols of every culture have been given a representation in a digital code called *Unicode*. *Unicode* uses a set of sixteen 1s and 0s to form a sixteen-bit binary code for each symbol. For example, the uppercase letter V is *Unicode* 00000000 01010110, which translates to the base 10 number 86. Lowercase v has a separate code that translates to the base 10 number 118.

When a letter is assigned to a `char` variable, the variable actually stores the *Unicode* representation of the letter. Uppercase letters from A to Z have values from 65 through 90. Lowercase letters from a to z have values from 97 through 122. Because `char` is a primitive data type, `char` values can be compared with relational operators, as the code below demonstrates:

```
char letter1, letter2;
letter1 = 'a';
letter2 = 'A'
if (letter1 > letter2) {
 System.out.println("greater than") //greater than displayed
} else {
 System.out.println("less than")
}
```

The `CountLetters` application counts the frequency of letters in a string. Each letter in the string is first converted to uppercase and then the counter at the appropriate index is incremented. Since uppercase letters have a range from 65 to 90 in *Unicode*, offset array indexes are used to determine which element to update:

```
import java.util.Scanner;

public class CountLetters {

 public static void main(String[] args) {
 final int LOW = 'A'; //smallest possible value
 final int HIGH = 'Z'; //highest possible value
 int[] letterCounts = new int[HIGH - LOW + 1];
 Scanner input = new Scanner(System.in);
 String word;
 char[] wordLetters;
 int offset; //array index
```

**TIP** Assignment to a `char` variable requires single quotation marks around the character.

```

/* prompt user for a word */
System.out.print("Enter a word: ");
word = input.nextLine();

/* convert word to char array and count letter occurrences */
word = word.toUpperCase();
wordLetters = word.toCharArray();
for (int letter = 0; letter < wordLetters.length; letter++) {
 offset = wordLetters[letter] - LOW;
 letterCounts[offset] += 1;
}

/* show letter occurrences */
for (int i = LOW; i <= HIGH; i++) {
 System.out.println((char)i + ": " + letterCounts[i - LOW]);
}
}
}

```

Note the statements for creating a `char` array from a `String` object. First, the `char` array `wordLetters` was declared. Later, `wordLetters` was initialized using the `toCharArray()` method in the statement:

```
wordLetters = word.toCharArray();
```

The number of characters in the string determined the number of array elements.

### *type casting*

Type casting was used in the last statement of the `CountLetters` application `((char)i)` to produce labels for the contents of the array. Casting the `int` to a `char` produces the Unicode equivalent character for that number.

The `CountLetters` application produces output similar to:

```

Enter a word: algorithmically
A: 2
B: 0
C: 1
D: 0
E: 0
F: 0
G: 1
H: 1
I: 2
J: 0
K: 0
L: 3
M: 1
N: 0
O: 1
P: 0
Q: 0
R: 1
S: 0
T: 1
U: 0
V: 0
W: 0
X: 0
Y: 1
Z: 0

```

## Review: CountLetters

The CountLetters application is limited to counting letters in a single word. Modify the CountLetters application to count the letters in an entire phrase, which contains spaces. Care must be taken to ignore the spaces and any other nonalphanumeric character found in the phrase. Be sure to change comments and variable names appropriately so that the reader of the application code understands that the letters in a phrase are counted.

## Review: NameBackwards

Create a NameBackwards application that prompts the user for his or her name and then displays the name backwards.

## Searching an Array

### *linear search*

There are many ways to search an array for a specific value. The simplest searching algorithm is called *linear search* and works by proceeding from one array element to the next until the specified value is found or until the entire array has been searched. The Search class below contains a linear() method that returns the index of a specified int element. If the element is not found, then -1 is returned:

```
public class Search {

 /**
 * Returns the index of the element numToFind.
 * -1 returned if element not found.
 * pre: none
 * post: index of numToFind has been returned. -1 has been
 * returned if element not found.
 */
 public static int linear(int[] array, int numToFind) {
 int index = 0;

 while ((array[index] != numToFind) &&
 (index < array.length - 1)) {
 index += 1;
 }

 if (array[index] == numToFind) {
 return(index);
 } else {
 return(-1);
 }
 }
}
```

### Algorithm Analysis

Algorithm analysis includes measuring how efficiently an algorithm performs its task. A linear search sequentially checks each element of an array for a specified element. For an array with  $n$  objects, finding an element could take as many as  $n$  checks. This measure can be written as  $O(n)$ . This notation is called Big Oh notation and is a theoretical measure of an algorithm's efficiency.

The condition of the while statement checks all but the last element of the array, unless the search element is found earlier. If the while statement completes without finding the element, the index value has been incremented to the last index of the array. The if statement then checks the last element of the array.

The application below uses the linear() method to find an element in the array:

```
import java.util.Scanner;
import java.util.Random;

public class FindNum {

 public static void main(String[] args) {
 final int MAX = 20;
 int[] numArray = new int[MAX];
 Random rand = new Random();
 Scanner input = new Scanner(System.in);
 int num, location;

 /* fill array with random numbers */
 for (int i = 0; i < numArray.length; i++) {
 numArray[i] = rand.nextInt(MAX);
 }

 /* prompt user for a number to search for */
 System.out.print("Enter a number between 0 and " + MAX
 + ": ");
 num = input.nextInt();

 /* Search for number and notify user of num location */
 location = Search.linear(numArray, num);
 if (location == -1) {
 System.out.println("Sorry, number not found in array.");
 } else {
 System.out.println("First occurrence is element "
 + location);
 }
 }
}
```

The FindNum application output looks similar to:

```
Enter a number between 0 and 20: 5
First occurrence is element 13
```

## Review: FindName

Add a `static` method to the `Search` class that performs a linear search on a `String` array. The `linear()` method should overload the existing method, have parameters for accepting a `String` array and a `String` variable, and return an `int` indicating the position of the `String`. Create a `FindName` application that uses the `Search` class. `FindName` should prompt the user for names to fill an array and then prompt the user for the name to find.

## Two-Dimensional Arrays

An array with two dimensions can be used to represent data that corresponds to a grid. For example, a checkerboard, the streets in a city, and seats in a theater can all be represented with a grid. A tic-tac-toe board represented in a two-dimensional array can be visualized as shown on the next page.

|   |   |   |   |
|---|---|---|---|
|   | 0 | 1 | 2 |
| 0 | X | O |   |
| 1 |   | O | X |
| 2 |   |   |   |

A two-dimensional array with three rows (0, 1, and 2) and three columns (0, 1, and 2) represents a tic-tac-toe board

#### declaration

A two-dimensional array must be declared and then space allocated for the elements of the array in statements that take the form:

```
<type>[][] <name>;
<name> = new <type>[<num>][<num>];
```

The declaration includes the type followed by two sets of brackets ([][]). The array name can be any valid identifier. The `new` operator allocates space for the number of elements indicated in brackets. For example, a tic-tac-toe board could be created with the statement:

```
String[][] tttBoard = new String[3][3];
```

#### length

The length property can be used to determine the number of rows and columns in a two-dimensional array with two separate statements:

```
rows = tttBoard.length;
cols = tttBoard[0].length;
```

Note that the number of columns is determined by checking the length of the first row.

#### accessing elements

An element of a two-dimensional array is accessed by including the indexes of the row and column in brackets after the array name. For example, the following statement assigns the element in the second row, third column the letter "X":

```
tttBoard[1][2] = "X";
```

#### nested for statements

Nested `for` statements are often used to access the elements of a two-dimensional array because one loop counter indicates the row and the second counter indicates the column. For example, the following statements display the contents of a two-dimensional array:

```
for(int row = 0; row < tttBoard.length; row++) {
 for (int col = 0; col < tttBoard[0].length; col++) {
 System.out.print(tttBoard[row][col]);
 }
 System.out.println();
}
```

#### array parameter

A method that requires a two-dimensional array parameter includes the array data type followed by two sets of brackets ([][]).

The TicTacToe application allows two players to play a computerized game of tic-tac-toe. The TTT class performs most of the work with `private` methods. The client code simply instantiates a TTT object and then calls the TTT object's `play()` method. The client code implementation is shown first and then the TTT class implementation:

```

 /**
 * Tic-tac-toe is played.
 */

 public class TicTacToe {

 public static void main(String[] args) {
 TTT TTTGame = new TTT();
 TTTGame.play();
 }
 }

 /**
 * TTT class.
 */

```

import java.util.Scanner;

```

 public class TTT {
 private String[][] tttBoard;
 private String player1, player2;

 /**
 * constructor
 * pre: none
 * post: tttBoard has been initialized.
 * player1 is X and player2 is O.
 */
 public TTT() {
 player1 = "X";
 player2 = "O";
 tttBoard = new String[3][3];
 for(int row = 0; row < tttBoard.length; row++) {
 for (int col = 0; col < tttBoard[0].length; col++) {
 tttBoard[row][col] = " ";
 }
 }
 }

 /**
 * Plays a game of tic-tac-toe with two users,
 * keeping track of player (X or O) turns.
 * player1 goes first.
 * pre: none
 * post: A game of tic-tac-toe has been played.
 */
 public void play() {
 String currPlayer = player1;
 int movesMade = 0;

 do {
 displayBoard();
 makeMove(currPlayer);
 movesMade += 1;
 if (currPlayer == player1){
 currPlayer = player2;
 } else {
 currPlayer = player1;
 }
 } while (movesMade <= 9 && winner() == " ");
 displayBoard();
 System.out.println("Winner is " + winner());
 }
 }
}

```

```

 /**
 * Displays the board.
 * pre: none
 * post: The tic-tac-toe board has been displayed.
 */
 private void displayBoard() {
 for(int row = 0; row < tttBoard.length; row++) {
 for (int col = 0; col < tttBoard[0].length; col++) {
 System.out.print("[" + tttBoard[row][col] + "]");
 }
 System.out.println();
 }
 }

 /**
 * Prompt user for a move until a valid move has been made.
 * pre: none
 * post: A mark has been made in an empty tic-tac-toe
 * board square.
 */
 private void makeMove(String player) {
 Scanner input = new Scanner(System.in);
 boolean validMove = false;
 int row, col;

 do {
 System.out.print("Enter row number (0, 1, 2): ");
 row = input.nextInt();
 System.out.print("Enter column number (0, 1, 2): ");
 col = input.nextInt();
 if ((row >= 0 && row < tttBoard.length &&
 col >= 0 && col < tttBoard[0].length) &&
 tttBoard[row][col].equals(" ")) {
 tttBoard[row][col] = player;
 validMove = true;
 } else {
 System.out.println("Invalid move. Try again.");
 }
 } while (!validMove);
 }

 /**
 * Determine winner. Return " " if no winner.
 * pre: none
 * post: X, O, or " " has been returned as the winner.
 */
 private String winner() {

 /* test rows */
 for (int row = 0; row < tttBoard.length; row++) {
 if (tttBoard[row][0].equals(tttBoard[row][1]) &&
 tttBoard[row][1].equals(tttBoard[row][2]) &&
 !(tttBoard[row][0].equals(" "))) {
 return(tttBoard[row][0]);
 }
 }
 }
}

```

```

/* test columns */
for (int col = 0; col < tttBoard[0].length; col++) {
 if (tttBoard[0][col].equals(tttBoard[1][col]) &&
 tttBoard[1][col].equals(tttBoard[2][col]) &&
 !(tttBoard[0][col].equals(" "))) {
 return(tttBoard[0][col]);
 }
}

/* test diagonal */
if (tttBoard[0][0].equals(tttBoard[1][1]) &&
 tttBoard[1][1].equals(tttBoard[2][2]) &&
 !(tttBoard[0][0].equals(" "))) {
 return(tttBoard[0][0]);
}

/* test other diagonal */
if (tttBoard[0][2].equals(tttBoard[1][1]) &&
 tttBoard[1][1].equals(tttBoard[2][0]) &&
 !(tttBoard[0][2].equals(" "))) {
 return(tttBoard[0][2]);
}
return(" ");
}
}

```

The TicTacToe application displays output similar to:

```

[][][]
[][][]
[][][]
Enter row number (0, 1, 2): 0
Enter column number (0, 1, 2): 0
[X][][]
[][][]
[][][]
Enter row number (0, 1, 2): 1
Enter column number (0, 1, 2): 1
[X][][]
[][0][]
[][][]
Enter row number (0, 1, 2): 1
Enter column number (0, 1, 2): 0
[X][][]
[X][0][]
[][][]
Enter row number (0, 1, 2): 2
Enter column number (0, 1, 2): 2
[X][][]
[X][0][]
[][][0]
Enter row number (0, 1, 2): 2
Enter column number (0, 1, 2): 0
[X][][]
[X][0][]
[X][][0]
Winner is X

```

# The ArrayList Class

*collection*

*collections framework*

**TIP** The ArrayList class is a data structure. Data structures are discussed further in Chapter 14.

## Data Structure Analysis

Data structure analysis includes measuring the efficiency of a data structure's operations. For example, adding an object to the end of an ArrayList data structure requires a single operation, which can be written as  $O(1)$ . However, adding an object to the beginning of the array requires all the existing objects first be moved up one position. For an array with  $n$  objects, adding an object to the front of the array requires  $n$  operations, which can be written as  $O(n)$ . This is a much less efficient operation.

*dynamic array*

*equals()*

A *collection* is a group of related objects, or elements, that are stored together as a single unit. An array is an example of a collection. Java also contains a *collections framework*, which provides classes for implementing collections. One such class is the ArrayList class, which includes methods for adding and deleting elements and finding an element.

Class ArrayList (java.util.ArrayList)

Method

`add(int index, Object element)`

inserts `element` at `index` position of the array. Existing elements are shifted to the next position up in the array.

`add(Object element)`

adds `element` to the end of the array.

`get(int index)`

returns the `element` at `index` position in the array.

`indexOf(Object obj)`

returns the `index` of the first element matching `obj` using the `equals()` method of the object's class to determine equality between the element and the object.

`remove(int index)`

removes the element at `index` position in the array.

`set(int index, Object element)`

replaces the element at `index` position with `element`.

`size()`

returns the number of elements in the array.

The ArrayList class implements a dynamic array. A *dynamic array* varies in size during run time and is used in applications where the size of an array may need to grow or shrink. An ArrayList object shifts elements up one position when a new element is added at a specific index. Elements added to the end of the ArrayList do not move existing elements. Removing an element from an ArrayList also shifts elements as necessary to close the gap left by the removed element.

When using an ArrayList object, it is important to understand that only objects, not primitive types, can be stored. Because the `indexOf()` method compares its `object` parameter to each element of the array, it is important that the object's class has an appropriately overridden `equals()` method.

The following application creates an ArrayList object, adds elements, removes an element, and then displays the remaining elements:

```
import java.util.ArrayList;

public class TestArrayList {

 public static void main(String[] args) {
 ArrayList myStrings = new ArrayList();

 myStrings.add("Kermit");
 myStrings.add("Lucille");
 myStrings.add("Sammy");
 myStrings.add("Roxy");
 myStrings.add("Myah");

 myStrings.remove(3);

 for (Object name : myStrings) {
 System.out.println(name);
 }
 }
}
```

**TIP** The for-each statement is not a safe structure for finding and removing elements from an ArrayList.

The ArrayList declaration does not require an array size. An ArrayList object grows and shrinks automatically as elements are added and removed. The for-each statement traverses the ArrayList. An ArrayList converts elements to their superclass Object, which is why `name` is type Object, rather than String.

The TestArrayList application displays the output:

```
Kermit
Lucille
Sammy
Myah
```

## Wrapper Classes

**TIP** Java also includes the Character, Boolean, Byte, Short, Long, and Float wrapper classes.

Primitive data types cannot be directly stored in an ArrayList because the elements in an ArrayList must be objects. The Integer and Double classes, provided with Java, are used to “wrap” primitive values in an object. The Integer and Double *wrapper classes* include the methods for comparing objects and for returning the value stored by the object as a primitive:

**Class Integer (java.lang.Integer)**

**Method**

`compareTo(Integer int0bject)`

returns 0 when the Integer object value is the same as `int0bject`. A negative `int` is returned when the Integer object is less than `int0bject`, and a positive `int` is returned when the Integer object is greater than `int0bject`.

`intValue()`

returns the `int` value of the Integer object.

**TIP** The Integer and Double classes implement the Comparable interface, introduced in Chapter 9.

### Class Double (java.lang.Double)

#### Method

`compareTo(Double doubleObject)`

returns 0 when the Double object value is the same as `doubleObject`. A negative `int` is returned when the Double object is less than `doubleObject`, and a positive `int` is returned when the Double object is greater than `doubleObject`.

`doubleValue()` returns the `double` value of the Double object.

The Integer and Double wrapper classes are in the `java.lang` package. Therefore applications do not require an `import` statement to use the wrapper classes.

The DataArrayList application creates an `ArrayList` of `Integer` values, compares the values, and then sums the elements:

```
import java.util.ArrayList;
public class DataArrayList {
 public static void main(String[] args) {
 ArrayList numbers = new ArrayList();
 Integer element, element1, element2;
 int sum = 0;
 numbers.add(new Integer(5));
 numbers.add(new Integer(2));
 /* compare values */
 element1 = (Integer)numbers.get(0);
 element2 = (Integer)numbers.get(1);
 if (element1.compareTo(element2) == 0) {
 System.out.println("The elements have the same value.");
 } else if (element1.compareTo(element2) < 0) {
 System.out.println("element1 value is less than element2.");
 } else {
 System.out.println("element1 value is greater than element2.");
 }
 /* sum values */
 for (Object num : numbers) {
 element = (Integer)num;
 sum += element.intValue();
 }
 System.out.println("Sum of the elements is: " + sum);
 }
}
```

In the first `numbers.add()` statement above, the `new` operator allocates memory and returns a reference to the `Integer` object that stores the value 5. A second statement performs the same type of action to add another `Integer` object to the `ArrayList`.

The values stored in the elements are compared using the `compareTo()` method. Note that the elements are first assigned to `Integer` objects `element1` and `element2`. The assignment statement must appropriately cast the retrieved values because an `ArrayList` casts elements to their superclass `Object`.

Finally, the `for-each` statement traverses the `ArrayList` elements and sums their values. The `(Integer)` cast is again required to convert the retrieved value `num` for assignment to `element`. The `int` value of each `Integer` object is then used to update `sum`.

## Generic Collection Classes

`ArrayList` items can be declared when the `ArrayList` is created. For example:

```
ArrayList<Integer> numbers = new ArrayList<Integer>;
```

designates the `ArrayList` as a list of `Integers`. This allows the `ArrayList` `get()` method to be used without casting. For example:

```
element1 = numbers.get(0);
```

returns an `Integer` object without the need to cast.

### object casting

The DataArrayList displays the output:

```
element1 value is greater than element2.
Sum of the elements is: 7
```

## Review: HighestGrade

Create a HighestGrade application that prompts the user for five grades between 0 and 100 points and stores the grades in an ArrayList. HighestGrade then traverses the grades to determine the highest grade and then displays the grade along with an appropriate message.

## Chapter 10 Case Study

**TIP** A Bank application was also developed in Chapter 8.

In this case study, a bank application will be created. A bank can open new accounts, modify existing accounts, and close accounts. An account has a number associated with it, and transactions, such as deposits and withdrawals, require the account number.

### LocalBank Specification

The LocalBank application allows accounts to be opened, modified, and closed. Each account has a unique account number, which is required for all transactions. Transactions include deposits and withdrawals. An account balance can also be checked.

The LocalBank interface should provide a menu of options. Depending on the option selected, additional input may be needed. When a transaction is performed, updated account information should be displayed. The LocalBank output sketch:

```
Deposit\Withdrawal\Check balance
Add an account\Remove an account
Quit

Enter choice: a
First name: Adriana
Last name: Lee
Beginning balance: 100
Account created. Account ID is: ALee

Deposit\Withdrawal\Check balance
Add an account\Remove an account
Quit

Enter choice: D
Enter account ID: ALee
Deposit amount: 22
ALee
Adriana Lee
Current balance is $122

Deposit\Withdrawal\Check balance
Add an account\Remove an account
Quit

Enter choice:
```

The LocalBank algorithm:

1. Display a menu of options.
2. Prompt the user for a menu choice.
3. For all options except the option to add an account, prompt the user for an account number.
4. Perform the action requested by the user on the account with the number entered. If the user requested to create a new account, then add an account and display the new account's number.
5. Repeat steps 1 through 4 until the user has selected the option to quit.

### LocalBank Code Design

The LocalBank application can be modeled with a Bank object, Account objects, and Customer objects. The Bank object should store the accounts, add and remove accounts, and perform transactions that also display updated account information. A transaction requires finding the correct account. The Account objects should store the current balance, make deposits, make withdrawals, and return the current balance and account ID. An Account object must also have an equals() method for the Bank object to use when finding an account. The Customer objects should store the account holder's name. The Bank object will display account information, therefore, the Account and Customer objects will override the toString() methods.

The LocalBank class designs are:

Bank

variables: accounts

methods:

addAccount – prompts the user for new account information. Displays the account number.

deleteAccount – removes an account. Requires a parameter for the account number.

transaction – performs a deposit or withdrawal. Requires parameters for the transaction code, account ID, and amount.

checkBalance – Displays account information, including current balance. Requires a parameter for the account ID.

## Account

variables: balance, Customer cust

methods:

getID – returns the account ID.

getBalance – returns the current balance.

deposit – increases the balance. Requires parameter for amount.

withdrawal – decreases the balance. Requires parameter for amount. If balance is less than withdrawal, then balance left unchanged.

equals – returns true when another Account object has the same ID as the object, returns false otherwise.

Requires a parameter for the other object.

toString – returns string with customer information and current balance.

## Customer

variables: firstName, lastName

methods:

toString() – returns a string with customer information.

The Account and Customer class designs are similar to the classes developed in Chapter 8. In the real world, the existing classes would probably be reused for the LocalBank application. The modularity of OOP makes programming more efficient and less error-prone. For this case study, simplified classes will be developed and used for the application.

Based on the algorithm and the class designs, the LocalBank code design will include a loop. The pseudocode for the LocalBank client code follows:

```
Bank easySave = new Bank();
do {
 prompt user for transaction type

 if (add account) {
 easySave.addAccount();
 } else if (not Quit) {
 prompt user for account ID;
 if (deposit) {
 prompt user for deposit amount
 easySave.transaction(make deposit, acctID, amt);
 } else if (withdrawal) {
 prompt user for withdrawal amount
 easySave.transaction(make withdrawal, acctID, amt);
 } else if (check balance) {
 easySave.checkBalance(acctID);
 } else if (remove account) {
 easySave.deleteAccount(acctID);
 }
 }
} while (not quit);
```

## LocalBank Implementation

The LocalBank implementation involves creating four files. Three files are the classes and one file is the client code.

The Bank class is implemented below:

```
/**
 * Bank class.
 */

import java.util.ArrayList;
import java.util.Scanner;

public class Bank {
 private ArrayList accounts;

 /**
 * constructor
 * pre: none
 * post: accounts has been initialized.
 */
 public Bank() {
 accounts = new ArrayList();
 }

 /**
 * Adds a new account to the bank accounts.
 * pre: none
 * post: An account has been added to the bank's accounts.
 */
 public void addAccount() {
 Account newAcct;
 double bal;
 String fName, lName;
 Scanner input = new Scanner(System.in);

 System.out.print("First name: ");
 fName = input.nextLine();
 System.out.print("Last name: ");
 lName = input.nextLine();
 System.out.print("Beginning balance: ");
 bal = input.nextDouble();

 newAcct = new Account(bal, fName, lName); //create acct object
 accounts.add(newAcct); //add account to bank accounts

 System.out.println("Account created. Account ID is: " + newAcct.getID());
 }

 /**
 * Deletes an existing account.
 * pre: none
 * post: An existing account has been deleted.
 */
 public void deleteAccount(String acctID) {
 int acctIndex;
 Account acctToMatch;
```

```

acctToMatch = new Account(acctID);
acctIndex = accounts.indexOf(acctToMatch); //retrieve location of account
if (acctIndex > -1) {
 accounts.remove(acctIndex); //remove account
 System.out.println("Account removed.");
} else {
 System.out.println("Account does not exist.");
}
}

/***
 * Performs a transaction on an existing account. A transCode of 1 is for deposits
 * and a transCode of 2 is for withdrawals.
 * pre: transCode is 1 or 2.
 * post: A transaction has occurred for an existing account.
 */
public void transaction(int transCode, String acctID, double amt) {
 int acctIndex;
 Account acctToMatch, acct;

 acctToMatch = new Account(acctID);
 acctIndex = accounts.indexOf(acctToMatch); //retrieve location of account
 if (acctIndex > -1) {
 acct = (Account)accounts.get(acctIndex); //retrieve object to modify
 if (transCode == 1) {
 acct.deposit(amt);
 accounts.set(acctIndex, acct); //replace object with updated object
 System.out.println(acct);
 } else if (transCode == 2) {
 acct.withdrawal(amt);
 accounts.set(acctIndex, acct); //replace object with updated object
 System.out.println(acct);
 }
 } else {
 System.out.println("Account does not exist.");
 }
}

/***
 * Displays the account information, including the current balance,
 * for an existing account.
 * pre: none
 * post: Account information, including balance, has been displayed.
 */
public void checkBalance(String acctID) {
 int acctIndex;
 Account acctToMatch, acct;

 acctToMatch = new Account(acctID);
 acctIndex = accounts.indexOf(acctToMatch); //retrieve location of account
 if (acctIndex > -1) {
 acct = (Account)accounts.get(acctIndex); //retrieve object to display
 System.out.println(acct);
 } else {
 System.out.println("Account does not exist.");
 }
}

```

In the deleteAccount() and transaction() methods, a new Account object is created for the purposes of finding the account to delete or modify. The new Account object is instantiated with just the acctID and then this object is passed to the indexOf() method of the ArrayList class. The indexOf()

method searches the ArrayList and automatically invokes the equals() method of the Account class to determine equality. The Account class is implemented below. Note that the equals() method requires only that the account numbers of two object match to be considered equal:

```
/**
 * Account class.
 */

import java.text.NumberFormat;

public class Account {
 private double balance;
 private Customer cust;
 private String acctID;

 /**
 * constructor
 * pre: none
 * post: An account has been created. Balance and
 * customer data has been initialized with parameters.
 */
 public Account(double bal, String fName, String lName) {
 balance = bal;
 cust = new Customer(fName, lName);
 acctID = fName.substring(0,1) + lName;
 }

 /**
 * constructor
 * pre: none
 * post: An empty account has been created with the specified account ID.
 */
 public Account(String ID) {
 balance = 0;
 cust = new Customer("", "");
 acctID = ID;
 }

 /**
 * Returns the account ID.
 * pre: none
 * post: The account ID has been returned.
 */
 public String getID() {
 return(acctID);
 }

 /**
 * Returns the current balance.
 * pre: none
 * post: The account balance has been returned.
 */
 public double getBalance() {
 return(balance);
 }
}
```

```

/**
 * A deposit is made to the account.
 * pre: none
 * post: The balance has been increased by the amount of the deposit.
 */
public void deposit(double amt) {
 balance += amt;
}

/**
 * A withdrawal is made from the account if there is enough money.
 * pre: none
 * post: The balance has been decreased by the amount withdrawn.
 */
public void withdrawal(double amt) {
 if (amt <= balance) {
 balance -= amt;
 } else {
 System.out.println("Not enough money in account.");
 }
}

/**
 * Returns a true when objects have matching account IDs.
 * pre: none
 * post: true has been returned when the objects are equal,
 * false returned otherwise.
 */
public boolean equals(Object acct) {
 Account testAcct = (Account)acct;
 if (acctID.equals(testAcct.acctID)) {
 return(true);
 } else {
 return(false);
 }
}

/**
 * Returns a String that represents the Account object.
 * pre: none
 * post: A string representing the Account object has been returned.
 */
public String toString() {
 String accountString;
 NumberFormat money = NumberFormat.getCurrencyInstance();

 accountString = acctID + "\n";
 accountString += cust.toString();
 accountString += "Current balance is " + money.format(balance);
 return(accountString);
}
}

```

The Account class has two constructors. The second constructor is used in the deleteAccount() and transaction() methods of the Bank class for the purposes of finding the index of the account matching the given account ID.

The Customer class is implemented below:

```
/**
 * Customer class.
 */

public class Customer {
 private String firstName, lastName;

 /**
 * constructor
 * pre: none
 * post: A Customer object has been created.
 * Customer data has been initialized with parameters.
 */
 public Customer(String fName, String lName) {
 firstName = fName;
 lastName = lName;
 }

 /**
 * Returns a String that represents the Customer object.
 * pre: none
 * post: A string representing the Customer object has
 * been returned.
 */
 public String toString() {
 String custString;

 custString = firstName() + " " + lastName() + "\n";
 return(custString);
 }
}
```

The LocalBank client code is implemented below:

```
/**
 * A bank where accounts can be opened or closed and customers can
 * make transactions.
 */

import java.util.Scanner;

public class LocalBank {

 public static void main(String[] args) {
 Bank easySave = new Bank();
 Scanner input = new Scanner(System.in);
 String action, acctID;
 Double amt;

 /* display menu of choices */
 do {
 System.out.println("\nDeposit\\Withdrawal\\Check balance");
 System.out.println("Add an account\\Remove an account");
 System.out.println("Quit\n");
 System.out.print("Enter choice: ");
 action = input.next();
```

```

 if (action.equalsIgnoreCase("A")) {
 easySave.addAccount();
 } else if (!action.equalsIgnoreCase("Q")) {
 System.out.print("Enter account ID: ");
 acctID = input.nextInt();
 if (action.equalsIgnoreCase("D")) {
 System.out.print("Enter deposit amount: ");
 amt = input.nextDouble();
 easySave.transaction(1, acctID, amt);
 } else if (action.equalsIgnoreCase("W")) {
 System.out.print("Enter withdrawal amount: ");
 amt = input.nextDouble();
 easySave.transaction(2, acctID, amt);
 } else if (action.equalsIgnoreCase("C")) {
 easySave.checkBalance(acctID);
 } else if (action.equalsIgnoreCase("R")) {
 easySave.deleteAccount(acctID);
 }
 }
 } while (!action.equalsIgnoreCase("Q"));
}

```

Running the LocalBank application displays output similar to:

```

Deposit\Withdrawal\Check balance
Add an account\Remove an account
Quit

Enter choice: a
First name: Sam
Last name: Iam
Beginning balance: 100
Account created. Account ID is: $Iam

Deposit\Withdrawal\Check balance
Add an account\Remove an account
Quit

Enter choice: D
Enter account ID: $Iam
Enter deposit amount: 22
$Iam
Sam Iam
Current balance is $122

Deposit\Withdrawal\Check balance
Add an account\Remove an account
Quit

Enter choice:

```

It was possible to create the LocalBank application with fewer classes. However, by breaking the application into discrete objects, it will be easier to later extend the classes to enhance the client code. For example, an account can easily be extended to include an account holder's address by modifying, or extending, the Customer class. Then, only the first constructor of the Account class will need to be modified to handle additional parameters for creating a Customer object.

## LocalBank Testing and Debugging

When a new class is written, client code should be written to test the class. Testing should be done first for each class and then for the client code.

## Review: LocalBank

Modify the Bank class to prompt the user for a full address (street, city, state, and zip) when an account is opened. Modify the Customer class to include street, city, state, and zip variable members and changeStreet(), changeCity(), changeState(), and changeZip() method members. Modify the Account class to include a changeAddress() method member. Modify the Bank class to include a modifyAccount() method member that requires a parameter for the account ID. modifyAccount() should prompt the user for the new street, city, state, and zip for the account, find the account with the matching account ID, and then overwrite the existing account object with the object containing the updated information.

## Chapter Summary

This chapter discussed arrays as a structure for storing many of the same kind of data together at once. A data item stored by an array is called an element. An element has an index value and is accessed by using the index inside of [] brackets along with the array name. A `for` statement and the `for-each` statement can be used to access all the elements of an array. Accessing the elements of an array is called traversing the array. When the index of an element is needed, the `for` statement should be used.

An array can be passed to a method as a parameter and is a reference data type. Passing a single element passes the data stored, not a reference to the data location.

Many algorithms make use of the index value of an array element for simplifying the storage and retrieval of data. Offset array indexes are used when a range should be shifted to correlate to a lower range of index values.

A String can be converted to an array of characters so that individual characters can be manipulated. Unicode is the standard for numeric representation of every letter and symbol in use.

The linear search is an algorithm for searching an array where each element is checked one after the other until the desired element is found.

Two-dimensional arrays represent data that corresponds to a grid. The number of rows in an existing two-dimensional array corresponds to the length of the array. The number of columns corresponds to the length of the first row. Elements in a two-dimensional array are accessed by using a double bracket ([][])) along with the array name.

The `ArrayList` class is used for storing a collection of objects. Methods are used for accessing and retrieving elements and for determining the number of elements in the collection. An `ArrayList` object is a dynamic array, which can vary in size at run time. Because an `ArrayList` can store only objects, wrapper classes are used to represent primitive types that are to be stored in an `ArrayList`.

## Vocabulary

**Array** A structure that can store many of the same kind of data together at once.

**ArrayOutOfBoundsException** An exception thrown when an invalid array index is used.

**Collection** A group of related elements that are stored together as a single unit.

**Collections framework** Classes for implementing collections.

**Dynamic array** An array that varies in size at run time.

**Element** A data item in an array.

**Index** The value associated with an element in an array. Index values begin at 0 and count up.

**Linear search** An algorithm for searching an array in which each element of the array is checked one after the other.

**Traversing** Iterating through element of an array.

**Unicode** The sixteen-bit digital code used to represent every letter and symbol.

**Wrapper class** A class that wraps primitive values in an object.

## Java

`[]` The operators for accessing an array element.

**ArrayList** A `java.util` class with methods for implementing a dynamic array.

**Double** A `java.lang` class for wrapping `double` values in an object.

**for** A statement that can be used to traverse an array. In one form, it is referred to as a `for-each` statement and does not use a counter variable.

**Integer** A `java.lang` class for wrapping `int` values in an object.

**new** Operator that allocates space for the elements in an array.

**String** A `java.lang` class with methods for converting a string to a set of characters or for inspecting individual characters of a string.

## Critical Thinking

1. What index value does the third element of an array have?
2. Write the declaration for an array named `quantities` that stores 20 integers.
3. Write a declaration for an array named `heights` storing the numbers 1.65, 2.15, and 4.95.
4. Write a `for-each` statement that displays the integer values stored in an array named `grades`.
5.
  - a) Write an algorithm for inserting data into an array so that existing data is moved up one position to make room for the new data.
  - b) Write an algorithm for deleting data from an array so that existing data is moved to close the gap made by the deleted data.
6. How does passing an entire array to a method differ from passing a single element of the array?
7. Why are offset array indexes required in some cases.
8. What output is displayed by the statements below?

```
String name = "Elaine";
System.out.println(name.charAt(3));
```
9. Compare and contrast an array to an `ArrayList` by describing the differences between the two for:
  - a) accessing an element.
  - b) adding an element.
  - c) deleting an element.
  - d) assigning a new value to an element.
  - e) determining the size of the collection.
10. Give an example of when a dynamic array might be a better structure choice over an array.
11. How does the `ArrayList indexOf()` method determine equality between the object passed to the method and an element in the array?
12. How can the values of wrapper class objects be compared?

### True/False

13. Determine if each of the following are true or false. If false, explain why.
  - a) All data in an array has the same data type.
  - b) Index values always begin at 0.
  - c) The statement `int[] empNums = new int[10]` declares an array with 10 elements.
  - d) In the statement `int[] empNums = new int[10]`, the elements are automatically initialized to 1.
  - e) An entire array can be passed to a method.
  - f) The method `toCharArray()` converts a `String` object to a `char` array.
  - g) A linear search never searches an entire array.
  - h) The statement `int[][] grid = new int[4][4]` declares a total of eight elements.
  - i) In Unicode, uppercase letters have higher base 10 number values than lowercase letters.
  - j) The size of an array can change during the execution of a program.
  - k) The `ArrayList` class implements a dynamic array.
  - l) Primitive data types can be stored directly in an `ArrayList`.

## Exercises

### Exercise 1

### EvensAndOdds

Create an EvensAndOdds application that generates 25 random integers between 0 and 99 and then displays all the evens on one line and all the odds on the next line. Application output should look similar to:

```
ODD:
21 21 87 39 45 7 75 71 87 9 81 27 57
EVEN:
26 64 2 74 0 40 84 0 82 0 32 90
```

### Exercise 2

### GeneratedNums

Create a GeneratedNums application that generates the number to store in an array element by summing its index and the individual digits of the index. For example, the element with index 17 should store 25 ( $17 + 1 + 7 = 25$ ) and the element with index 2 should store 4 ( $2 + 0 + 2 = 4$ ). GeneratedNums should use an array with 101 elements and then display the value at each element. Application output should look similar to:

| Index | Generated Number |
|-------|------------------|
| 0     | 0                |
| 1     | 2                |
| 2     | 4                |
| 3     | 6                |
| 4     | 8                |
| 5     | 10               |
| 6     | 12               |
| 7     | 14               |
| 8     | 16               |
| 9     | 18               |
| 10    | 11               |
| 11    | 13               |
| 12    | 15               |
| 13    | 17               |

### Exercise 3

### RandomStats

Create a RandomStats application that generates 500 random numbers between 0 and 9 and then displays the number of occurrences of each number. Application output should look similar to:

| Number | Occurrences |
|--------|-------------|
| 0      | 56          |
| 1      | 47          |
| 2      | 49          |
| 3      | 49          |
| 4      | 55          |
| 5      | 49          |
| 6      | 59          |
| 7      | 36          |
| 8      | 42          |
| 9      | 58          |

## Exercise 4

## Analysis

A program that analyzes a set of numbers can be very useful. Create an Analysis application that prompts the user for numbers in the range 1 through 50, terminated by a sentinel, and then performs the following analysis on the numbers:

- Determine the average number
- Determine the maximum number
- Determine the range (maximum – minimum)
- Determine the median (the number that occurs the most often)
- Displays a bar graph called a histogram that shows the numbers in each five-unit range (1–5, 6–10, 11–15, etc.). The histogram may look similar to:

|    |   |    |   |       |
|----|---|----|---|-------|
| 1  | - | 5  | : | **    |
| 6  | - | 10 | : | ***** |
| 11 | - | 15 | : | ***** |
| 16 | - | 20 | : | ****  |
| 21 | - | 25 | : | ***   |
| 26 | - | 30 | : | **    |
| 31 | - | 35 | : | ***** |
| 36 | - | 40 | : | ****  |
| 41 | - | 45 | : | ***** |
| 45 | - | 50 | : | ****  |

## Exercise 5

## Mastermind

The game of Mastermind is played as follows: One player (the code maker) chooses a secret arrangement of colored pegs and the other player (the code breaker) tries to guess it. For each guess, the code breaker puts forth an arrangement of colored pegs, and the code maker reports two numbers:

1. The number of pegs that are the correct color and in the correct position.
2. The number of pegs that are the correct color regardless of whether they are in the correct position.

Create a Mastermind application that plays the game of Mastermind with the computer as the code maker and the user as the code breaker. The application should use a mastermindGame class, which has a constructor with parameters for the number of pegs in the code (1 to 10) and the number of colors for the pegs (1 to 9). The secret code generated by a mastermindGame object can contain duplicate colors. For example, a 5-peg code could be 1 2 2 5 6. A guess with duplicates will require extra attention when counting the number of pegs of the correct color. For example, if the code is 1 2 3 4 5 6 and the guess is 2 1 1 2 2 2, then the mastermindGame object should only report two correct colors (a single 1 and a single 2). Application output should look similar to:

```
Enter the number of pegs (1-10): 3
Enter the number of colors (1-9): 5

Guess 1:
Color for peg 1: 2
Color for peg 2: 4
Color for peg 3: 3
You have 0 peg(s) correct and 2 color(s) correct.

Guess 2:
Color for peg 1: 3
Color for peg 2: 2
Color for peg 3: 4
You have 2 peg(s) correct and 2 color(s) correct.

Guess 3:
Color for peg 1: 1
Color for peg 2: 2
Color for peg 3: 4
You have 2 peg(s) correct and 2 color(s) correct.

Guess 4:
Color for peg 1: 5
Color for peg 2: 2
Color for peg 3: 4
You have 3 peg(s) correct and 3 color(s) correct.

You have broken the code in 4 guesses.
```

## Exercise 8

## Palindrome

Create a Palindrome application that prompts the user for a string and then displays a message indicating whether or not the string is a palindrome. A palindrome is a word or phrase that is spelled the same backwards and forwards. For example, “mom” is a palindrome, as well as “kayak” and “Never odd or even”.

## Exercise 9

## CountConsonants

Create a CountConsonants application that prompts the user for a string and then displays the number of consonants in the string. Application output should look similar to:

```
Enter text: spring flowers
The number of consonants in spring flowers is 10
```

## Exercise 10

## Coder

Create a Coder application that prompts the user for a string and then displays an encoded string. The encoding should add 2 to the Unicode value of each letter to create a new letter. The application should keep all spaces between the words in their original places and the letters x and y should be converted to a and b, respectively. Coder application output should look similar to:

```
Enter a string: hello there
Encoded Message: jgnnq vjgtg
```

## Exercise 11

## SortedArray

An array is said to be sorted if its elements are in either increasing or decreasing order. One way the selection sort algorithm works is by repeatedly taking the lowest element from an array and adding it to a new array, so that all the elements in the new array are sorted from lowest to highest.

Create a SelectionSort class with a constructor that has an `int` array parameter, member variables `originalArray` and `sortedArray`, `public` method `display()` that displays the contents of the sorted array, `private` methods `sort()` that populates a new array with the elements of the original array in order from lowest to highest, and `findLowest()` that returns the index of the element containing the lowest value. Hint: Since elements of an array cannot actually be “removed” an element can be set to a very high value after determining its value is the lowest.

Create client code `SortedArray`, which tests the `SelectionSort` class. Use the pseudocode below when implementing the `SortedArray` client code:

```
int[] myNums;
SelectionSort sortedArray;

prompt user for the number of values to populate array with
myNums = new int[values];
populate array with random integers between 0 and 100
display contents of original array

sortedArray = new SelectionSort(myNums);
sortedArray.display();
```

## Exercise 12

## CourseGrades

Create a `CourseGrades` application that simulates a grade book for a class with 12 students that each have 5 test scores. The `CourseGrades` application should use a `GradeBook` class that has member variables `grades`, which is a two-dimensional array of integers, and methods `getGrades()` for prompting the user for the test grades for each student, `showGrades()` that displays the grades for the class, `studentAvg()` that has a student number parameter and then returns the average grade for that student, and `testAvg()` that has a test number parameter and then returns the average grade for that test.

## Exercise 13

## PennyPitch

The Penny Pitch game is popular in amusement parks. Pennies are tossed onto a board that has certain areas marked with different prizes. For example:

|        |        |        |        |      |
|--------|--------|--------|--------|------|
| PUZZLE |        | POSTER |        | DOLL |
|        | POSTER |        | DOLL   | BALL |
|        | PUZZLE | GAME   |        |      |
| PUZZLE | BALL   |        | POSTER | GAME |
| DOLL   | GAME   |        |        | BALL |

The prizes available on this board are puzzle, game, ball, poster, and doll. At the end of the game, if all of the squares that say BALL are covered by a penny, the player gets the ball. This is also true for the other prizes. The board is made up of 25 squares ( $5 \times 5$ ). Each prize appears on three randomly chosen squares so that 15 squares contain prizes.

Create a PennyPitch application that displays a Penny Pitch board (use [ and ] to indicate squares) with prizes randomly placed and then simulates ten pennies being randomly pitched onto the board. After the pennies have been pitched, the application should display a message indicating which prizes have been won, if any.

## Exercise 14

### Life

The Game of Life was devised by mathematician John Conway in 1970. It models a very simple world. The Life world is a two-dimensional plane of cells. Each cell may be empty or contain a single creature. Each day, creatures are born or die in each cell according to the number of neighboring creatures on the previous day. A neighbor is a cell that adjoins the cell either horizontally, vertically, or diagonally. The rules in pseudocode style are:

```
if (the cell is alive on the previous day) {
 if (the number of neighbors was 2 or 3) {
 the cell remains alive
 } else {
 the cell dies
 }
} else if (the cell is not alive on the previous day) {
 if (the number of neighbors was exactly 3) {
 the cell becomes alive
 } else {
 the cell remains dead
 }
}
```

For example, the world displayed as:

```
0000000000
0000000000
000XXX0000
0000000000
0000000000
0000000000
0000000000
```

where X's indicate living cells, becomes:

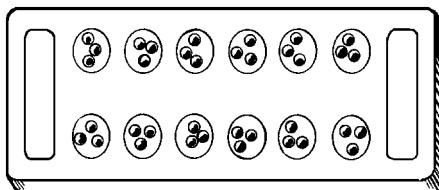
```
0000000000
0000X00000
0000X00000
0000X00000
0000000000
0000000000
```

Create a Life application that has a  $20 \times 20$  grid. To initialize the grid, the application should prompt the user for the coordinates of live cells on the first day. The application should then generate each day's world as long as the user wishes to continue or until there are no more live cells.

## Exercise 15

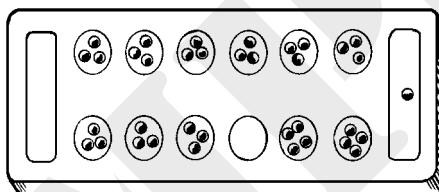
## Manacala

The game of Mankala is played on a board like that illustrated below:

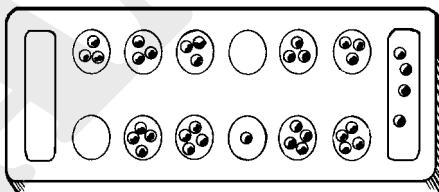


Players sit on opposite sides with the large bin to a player's right designated her home bin. On a turn, a player selects one of the six pits to remove the stones from and then "sows" the stones counterclockwise around the board, placing one stone in each pit including the player's home bin (but excluding the opponent's home bin). If the last stone lands in the player's home bin, the player gets another turn. If the last stone lands in an empty pit on the player's side of the board, the player takes all stones in the corresponding pit on the opponent's side and places them in the player's home bin. When a player cannot play, the game is over and all stones remaining in the opponent's pits go to the opponent's home bin. The winner is the player with the most stones in the player's home bin at the end of the game.

For example, if the bottom player plays first and chooses the fourth pit to play from, the board looks like:



Since the last stone landed in the player's home bin, the player takes another turn. The player may choose the first pit this time in order to capture the opponent's stones:



The player's turn is now over, and the opponent now has a turn.

Create a Mancala application. The application should use simple characters to illustrate the board, and letters to identify the pits, similar to that shown below:

|   |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|---|
|   | 3 | 3 | 3 | 3 | 3 | 3 |   |
| 0 |   |   |   |   |   |   | 0 |
|   | 3 | 3 | 3 | 3 | 3 | 3 |   |
| A | B | C | D | E | F |   |   |

## Exercise 16

## Inventory

Create an Inventory application that keeps track of the inventory for a sports store. Each item has a stock number, with the first item having a stock number of 1000. The second item has a stock number 1001, the third has stock number 1002, and so on. Along with a stock number, each item has an item name and an amount in stock. New items can be added to the inventory at any time. When added, the item stock number is generated and displayed to the user. Discontinued items should not be deleted from the inventory, but rather their item name should be changed to “discontinued” and the amount in stock should be decreased to 0. The Inventory application should use an ArrayList for maintaining the inventory and application output should display a menu of choices, which allow for adding an item, discontinuing an item, and displaying the amount in stock for an item.

SAMPLE

SAMPLE

# Chapter 11

## GUIs and Event-Driven Programming

**S**wing is a Java package that provides a set of classes for creating graphical user interfaces (GUIs). This chapter explains how to use the basic Swing components to create applications with a GUI. Components covered in this chapter include frames, panels, labels, buttons, combo boxes, and text fields.

### What is a GUI?

A *GUI* is a graphical user interface (sometimes pronounced “gooey”). An application written for the Microsoft Windows or Mac OS X Tiger operating system typically has a GUI. The GUI below includes a frame, also called a window, and a label:



Not only does a GUI use components such as frames, buttons, and text fields to communicate with the user, but GUIs are event-driven. An *event-driven application* executes code in response to events. An *event* is an interaction from the user, such as a button click. A GUI responds to an event by executing a method called an *event handler*. For example, when the user clicks a button, the application must be able to determine which button was clicked and then execute the code that relates to that button.

### The Swing Package

The Swing API is part of the Java Foundation Classes (JFC) and contains numerous components for creating GUIs. This chapter focuses on the `javax.swing` package. Two classes in this package are `JFrame` and `JLabel`. The `JFrame` class is used to instantiate a frame. A *frame* is a window with a border, title, and buttons for minimizing, maximizing, and closing the frame. A frame is a top-level *container* for a GUI, which holds and displays all the other components of an interface in a *content frame*. One of the most common components in a content frame is a label. *Labels*, created with the `JLabel` class, are used to display text that cannot be changed by the user.

*event-driven application*

*event handler*

`javax.swing`  
`frame`

*container, content frame*

*labels*

The swing package includes the JFrame class with the following methods:

**Class JFrame (javax.swing.JFrame)**

**Method**

`setDefaultLookAndFeel(boolean)`  
sets the frames created after this class method is called to have Java Window decorations, such as borders and a title, when the boolean argument is true.

`setDefaultCloseOperation(class _ constant)`  
sets the operation that occurs when the user clicks the Close button. The class \_ constant argument is usually JFrame.EXIT \_ ON \_ CLOSE.

`getContentPane()`  
returns a Container object corresponding to the content pane.

`setContentPane(Container contentPane)`  
sets the content pane to contentPane. The Container class is the superclass for the JPanel class, a class for creating content panes.

`pack()`  
sizes the frame so that all of its contents are at or above their preferred sizes.

`setVisible(boolean)`  
displays the frame when the boolean argument is true.

#### **JPanel content pane**

A JFrame object uses a content pane to hold GUI components. A JPanel object is one choice for a simple content pane. The JPanel class includes the following methods for adding and removing components:

**Class JPanel (javax.swing.JPanel)**

**Method**

`add(Component GUIcomponent)`  
adds a GUIcomponent to the content pane. When added, components are given an index value, with the first component at index 0.

`remove(int index)`  
removes the component with index value index.

After adding components to the JPanel object, the content frame is added to the JFrame object using the JFrame setContentPane() method described above.

The swing package includes the JLabel class for creating labels that can be added to a content pane. JLabels have several constructors, two of which are described, in addition to the setText() method:

```

Class JLabel (javax.swing.JLabel)
Constructor/Method
JLabel(String str)
 creates a JLabel object with text str.

JLabel(String str, align _ constant)
 creates a JLabel object with text str and alignment align _ constant that can be set to JLabel class constants LEADING or TRAILING, which are left and right alignment, respectively.

setText(String str)
 sets the text of the JLabel object to str.

```

The HelloWorldWithGUI1 application creates a frame and a content pane, adds the content pane to the frame, and then displays the frame:

```

import javax.swing.*;

public class HelloWorldWithGUI1 {
 final static String LABEL_TEXT = "Hello, world!";
 JFrame frame;
 JPanel contentPane;
 JLabel label;

 public HelloWorldWithGUI1(){
 /* Create and set up the frame */
 frame = new JFrame("HelloWorldWithGUI");
 frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);

 /* Create a content pane */
 contentPane = new JPanel();

 /* Create and add label */
 label = new JLabel(LABEL_TEXT);
 contentPane.add(label);

 /* Add content pane to frame */
 frame.setContentPane(contentPane);

 /* Size and then display the frame. */
 frame.pack();
 frame.setVisible(true);
 }

 /**
 * Create and show the GUI.
 */
 private static void runGUI() {
 JFrame.setDefaultLookAndFeelDecorated(true);

 HelloWorldWithGUI1 greeting = new HelloWorldWithGUI1();
 }

 public static void main(String[] args) {
 /* Methods that create and show a GUI should be
 * run from an event-dispatching thread */
 javax.swing.SwingUtilities.invokeLater(new Runnable() {
 public void run() {
 runGUI();
 }
 });
 }
}

```

**TIP** The HelloWorldWithGUI1 application output is shown on the first page of this chapter.

The implementation of a Swing application is different from previous applications presented in this text. The controlling class contains a constructor and members in addition to the main() method. Therefore, the controlling class is actually used to instantiate an object, which implements the GUI.

The statement in the main() method runs the GUI from an event-  
*thread* dispatching thread. A *thread* is simply a process that runs sequentially from start to finish. GUIs should be invoked from an event-dispatching thread to ensure that each event-handler finishes executing before the next one executes. Thorough coverage of this topic is beyond the scope of this text. However, the code shown is needed in every application that implements a Swing GUI.

## Review: Name – part 1 of 2

Create a Name application that displays your name in a label inside a JFrame.

### The JButton Class

A button is a commonly used GUI component. A *button* can be clicked by the user to communicate with the application. For example, the HelloWorldWithGUI2 application includes a button that when clicked either hides or displays text in the label:



The swing package includes the JButton class for creating buttons:

Class JButton (javax.swing.JButton)  
Method  
JButton(String str)  
creates a JButton object displaying the text str.  
setActionCommand(String cmd)  
sets the name of the action performed when the button is clicked to cmd.  
getActionCommand()  
returns the name of the action that has been performed by the button.  
addActionListener(Object)  
adds an object that listens for the user to click this component.

Unlike a JLabel, a JButton can respond to interaction from the user.

## Handling Events

*listener*  
*action command*

Swing components use listeners to determine if an event has occurred. A *listener* is an object that listens for action events. When an event is heard, the listener responds by executing an event handler named `actionPerformed()`. The `actionPerformed()` method has an `ActionEvent` parameter passed by the GUI when an event occurs. The `ActionEvent` object includes an action command. An *action command* is a string describing an event, or action.

The `HelloWorldWithGUI2` application output is shown in the previous section. When the Hide button is clicked, the application GUI changes to display:



*this*

The `HelloWorldWithGUI2` application code is below. For this GUI, a JButton is created, the JButton action command is set, and the current object is the listener for JButton action events. Note the use of the keyword `this` for the listener object to indicate the `HelloWorldWithGUI2` object itself:

```
import javax.swing.*;
import java.awt.event.*;

public class HelloWorldWithGUI2 implements ActionListener {
 final static String LABEL_TEXT = "Hello, world!";
 JFrame frame;
 JPanel contentPane;
 JLabel label;
 JButton button;

 public HelloWorldWithGUI2(){
 /* Create and set up the frame */
 frame = new JFrame("HelloWorldWithGUI");
 frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);

 /* Create a content pane */
 contentPane = new JPanel();

 /* Create and add label */
 label = new JLabel(LABEL_TEXT);
 contentPane.add(label);

 /* Create and add button */
 button = new JButton("Hide");
 button.setActionCommand("Hide");
 button.addActionListener(this);
 contentPane.add(button);

 /* Add content pane to frame */
 frame.setContentPane(contentPane);

 /* Size and then display the frame. */
 frame.pack();
 frame.setVisible(true);
 }

}
```

```

 /**
 * Handle button click action event
 * pre: Action event is Hide or Show
 * post: Clicked button has different text, and label
 * displays message depending on when the button was clicked.
 */
 public void actionPerformed(ActionEvent event) {
 String eventName = event.getActionCommand();

 if (eventName.equals("Hide")) {
 label.setText(" ");
 button.setText("Show");
 button.setActionCommand("Show");
 } else {
 label.setText(LABEL_TEXT);
 button.setText("Hide");
 button.setActionCommand("Hide");
 }
 }

 /**
 * Create and show the GUI.
 */
 private static void runGUI() {
 JFrame.setDefaultLookAndFeelDecorated(true);

 HelloWorldWithGUI2 greeting = new HelloWorldWithGUI2();
 }

 public static void main(String[] args) {
 /* Methods that create and show a GUI should be
 * run from an event-dispatching thread */
 javax.swing.SwingUtilities.invokeLater(new Runnable() {
 public void run() {
 runGUI();
 }
 });
 }
}

```

**TIP** awt stands for Abstract Windows Toolkit.

A class that uses a listener must implement an ActionListener. This is done by adding `implements ActionListener` to the class declaration and then defining an `actionPerformed()` method, which is the only method in the `ActionListener` interface. An `import java.awt.event` statement is required to import the package containing the `ActionListener` interface.

The GUI is implemented in the constructor. The segment of code that creates and adds the button does four things. First, a button that displays Hide is created. Second, because the user will see a Hide button the action command associated with this button should be "Hide". Third, a listener is needed to determine when the user clicks the button. The listener is set to the `HelloWorldWithGUI2` object itself (`this`). Fourth, the button is added to the content pane.

The `actionPerformed()` method is passed an `ActionEvent` argument by the GUI when the button is clicked. `ActionEvent` objects have a `getActionCommand()` method. This method returns the string assigned as the object's action command. For the Show/Hide button, the action command, as well as the button text, is changed each time the button is clicked.

## Review: Name – part 2 of 2

Modify the Name application to display or hide your name depending on the button clicked by the user, similar to the HelloWorldWithGUI2 application.

## Review: NumClicks

Create a NumClicks application that contains a button displaying how many times the user has clicked that button. The application interface should look similar to the following after the user has clicked the button 12 times:



For this application it is not necessary to set the action command. A call to the `getActionCommand()` method in the `actionPerformed()` method is also not needed.

## Controlling Layout

### layout

*Layout* refers to the arrangement of components. In a Swing GUI, the layout of a content pane can be controlled by adding borders, using a layout manager, and setting alignments.

### borders

A border can be added to most components, including the content pane. An invisible, or empty, border can be used to add “padding” around a component to give it distance from other components. Adding an empty border to the content pane adds space between the components and the edges of the frame. For example, the content pane in the GUI on the left has no border, but the content pane on the right has an empty border of 20 pixels on the top, left, bottom, and right:



*An empty border in the content pane on the right provides padding between the components and the frame*

### layout manager

### FlowLayout manager

*A layout manager* determines the order of components on a content pane. There are many layout managers to choose from, including `FlowLayout`, `BoxLayout`, and `GridLayout`. The *FlowLayout manager* places components one next to the other in a row. When a row becomes too long, a new row is started. The `FlowLayout` manager is the default manager. The `HelloWorldWithGUI` applications use this manager.

### BoxLayout manager

The *BoxLayout manager* places components one after the other in a column, with one component per line. For example, the GUI below uses the BoxLayout manager:

**TIP** The BoxLayout manager also includes methods for adding “glue” and “rigid areas” to a layout to control placement of components.



*The BoxLayout manager places components one after the other in a column*

### GridLayout manager

The *GridLayout manager* places components into a grid of rows and columns. The intersection of a row and column is called a *cell*. There is one component per cell in a GridLayout. The GUI below uses a GridLayout. An additional button was added to illustrate the grid:



*The GridLayout manager places components into a grid of cells*

### alignment

Another factor that affects layout is alignment. *Alignment* refers to the placement of a component within a layout. For example, both GUIs below use a BoxLayout, have an empty border of 20, 20, 20, and 20 in the content pane, and a 20, 50, 20, 50 empty border around the window. The GUI on the left specifies no alignment for the components, and the GUI on the right center aligns the label and the button:



*Alignment affects the placement of components within a layout*

The HelloWorldWithGUI2 application modified to use a layout manager, borders, and alignment:

```

import javax.swing.*;
import java.awt.event.*;

public class HelloWorldWithGUI2 implements ActionListener {
 final static String LABEL_TEXT = "Hello, world!";
 JFrame frame;
 JPanel contentPane;
 JLabel label;
 JButton button;

 public HelloWorldWithGUI2(){
 /* Create and set up the frame */
 frame = new JFrame("HelloWorldWithGUI");
 frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);

 /* Create a content pane with a BoxLayout and
 empty borders */
 contentPane = new JPanel();
 contentPane.setLayout(new BoxLayout(contentPane,
 BoxLayout.PAGE_AXIS));
 contentPane.setBorder(BorderFactory.createEmptyBorder(20,20,20,20));

 /* Create and add label that is centered and
 has empty borders */
 label = new JLabel(LABEL_TEXT);
 label.setAlignmentX(JLabel.CENTER_ALIGNMENT);
 label.setBorder(BorderFactory.createEmptyBorder(20, 50, 20, 50));
 contentPane.add(label);

 /* Create and add button that is centered */
 button = new JButton("Hide");
 button.setAlignmentX(JButton.CENTER_ALIGNMENT);
 button.setActionCommand("Hide");
 button.addActionListener(this);
 contentPane.add(button);

 /* Add content pane to frame */
 frame.setContentPane(contentPane);

 /* Size and then display the frame. */
 frame.pack();
 frame.setVisible(true);
 }
}

...rest of HelloWorldWithGUI2 code

```

#### *setLayout() method*

The JPanel `setLayout()` method is used to specify a layout for the content pane. A `BoxLayout` object requires arguments for the content pane and the arrangement. To arrange components in a vertical line, the class constant `PAGE_AXIS` is specified.

#### *setBorder() method*

The JPanel `setBorder()` method is used to specify borders for the content pane. The `BorderFactory` class has many different kinds of borders to choose from. For invisible, or empty borders, the `createEmptyBorder()` method is used. The arguments specify the width of the top, left, bottom, and right of the border.

#### *setAlignment() method*

The JLabel and JButton `setAlignmentX()` methods are used to specify the vertical alignment of the components within the layout. Both classes include several alignment constants, including `CENTER_ALIGNMENT`.

**TIP** Experiment with the numerous types of borders.

The modified HelloWorldWithGUI2 application produces a GUI that looks similar to:



### GridLayout manager

**TIP** The GridLayout manager places components in rows from left to right in the order that they are added to the content pane.

[java.awt](#)

For GUIs with components that should be side by side in rows, the GridLayout manager may be a better choice. The GridLayout manager is specified in a statement similar to:

```
contentPane.setLayout(new GridLayout(0, 2, 10, 5))
```

The GridLayout object requires arguments for specifying the number of rows and columns and the space between columns and rows. If 0 is specified for either the rows or columns, the class creates an object with as many rows or columns as needed. However, only one argument can be 0. In the statement above, the GridLayout object will have as many rows as needed and 2 columns. There will be 10 pixels between columns and 5 pixels between rows. The GridLayout class is part of the java.awt package. Code using this manager requires an `import java.awt.*` statement.

## Review: Sunflower

Create a Sunflower application that displays the Latin name for the sunflower when Latin is clicked and the English name when English is clicked. The application GUI should use a BoxLayout manager and look similar to the following after Latin has been clicked:



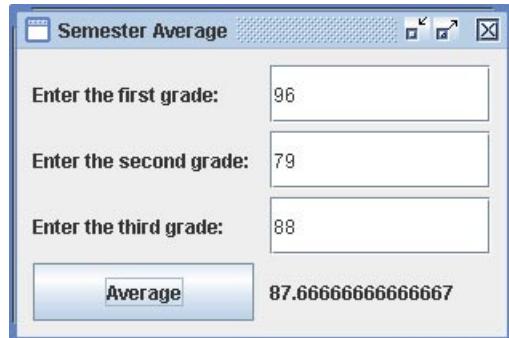
## Review: Riddle

Create a Riddle application that displays a riddle and then solves it when Answer is clicked. The application GUI should use a GridLayout manager and look similar to the following after Answer has been clicked:



## Getting Input from the User

A *text field* allows a user to enter information at run time. Text fields are usually placed next to a label to prompt the user for the type of data expected in the text field. For example, the SemesterAvg application prompts the user to enter three test grades and then displays the average of the grades when Average is clicked:



The swing package includes the JTextField class with the following constructors and methods:

**Class JTextField (javax.swing.JTextField)**

**Constructor/Methods**

`JTextField(int col)`

creates a JTextField object with width col.

`JTextField(String text, int col)`

creates a JTextField object displaying default text text in a field with width col.

`getText()`

returns a String containing the text in the JTextField.

`addActionListener(Object)`

adds an object that listens for the user to press the Enter key in this component.

### converting between text and numeric data

The information typed into a text field is a string, even when numeric data is entered. Conversely, the setText() method of a JLabel expects a string even when the data is numeric. Class methods in the Double and Integer classes can be used to convert data between numeric and String types:

**Class Double (java.lang.Double)**

**Method**

`parseDouble(String text)`

returns the double value in the String text.

`toString(double num)`

returns the String representation of num.

**Class Integer (java.lang.Integer)**

**Method**

`parseInt(String text)`

returns the int value in the String text.

`toString(int num)`

returns the String representation of num.

The `parseDouble()` and `parseInteger()` methods are used to convert String data to numeric. The SemesterAvg application, the GIUI shown on the previous page, uses `parseDouble()`:

```
import javax.swing.*;
import java.awt.*;
import java.awt.event.*;

public class SemesterAvg implements ActionListener {
 JFrame frame;
 JPanel contentPane;
 JLabel prompt1, prompt2, prompt3, average;
 JTextField grade1, grade2, grade3;
 JButton avgButton;

 public SemesterAvg(){
 /* Create and set up the frame */
 frame = new JFrame("Semester Average");
 frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);

 /* Create a content pane with a GridLayout */
 contentPane = new JPanel();
 contentPane.setLayout(new GridLayout(0, 2, 10, 5));
 contentPane.setBorder(BorderFactory.createEmptyBorder
 (10, 10, 10, 10));

 /* Create and add a prompt and then a text field */
 prompt1 = new JLabel("Enter the first grade: ");
 contentPane.add(prompt1);

 grade1 = new JTextField(10);
 contentPane.add(grade1);

 /* Create and add a second prompt and
 then a text field */
 prompt2 = new JLabel("Enter the second grade: ");
 contentPane.add(prompt2);

 grade2 = new JTextField(10);
 contentPane.add(grade2);

 /* Create and add a third prompt and then a text field */
 prompt3 = new JLabel("Enter the third grade: ");
 contentPane.add(prompt3);

 grade3 = new JTextField(10);
 contentPane.add(grade3);

 /* Create and add button that will display the
 average of the grades */
 avgButton = new JButton("Average");
 avgButton.setActionCommand("Average");
 avgButton.addActionListener(this);
 contentPane.add(avgButton);

 /* Create and add a label that will display the
 average */
 average = new JLabel(" ");
 contentPane.add(average);

 /* Add content pane to frame */
 frame.setContentPane(contentPane);
```

```

 /* Size and then display the frame. */
 frame.pack();
 frame.setVisible(true);
 }

 /**
 * Handle button click action event
 * pre: none
 * post: The average of the grades entered has been
 * calculated and displayed.
 */
 public void actionPerformed(ActionEvent event) {
 String eventName = event.getActionCommand();

 if (eventName.equals("Average")) {
 double avgGrade;
 String g1 = grade1.getText();
 String g2 = grade2.getText();
 String g3 = grade3.getText();

 avgGrade = (Double.parseDouble(g1) + Double.parseDouble(g2)
 + Double.parseDouble(g3))/3;
 average.setText(Double.toString(avgGrade));
 }
 }

 /**
 * Create and show the GUI.
 */
 private static void runGUI() {
 JFrame.setDefaultLookAndFeelDecorated(true);

 SemesterAvg myGrades = new SemesterAvg();
 }
}

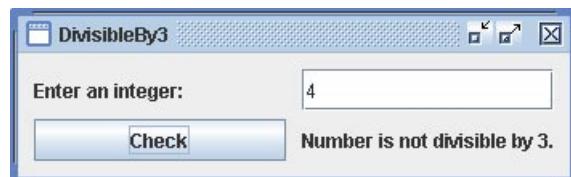
...main() method of SemesterAvg code

```

In the actionPerformed() method, the strings are read from the text fields. To calculate the average grade, each string is parsed for a `double` value (with `parseDouble()`). The `avgGrade` value was then converted to a String with the `Double` class method `toString()`.

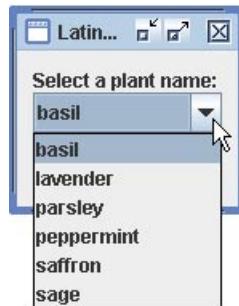
## Review: DivisibleBy3

Create a `DivisibleBy3` application that prompts the user for an integer and then displays a message when `Check` is clicked indicating whether the number is divisible by 3. The application interface should look similar to the following after the user has typed a number and clicked `Check`:



## Combo Boxes

A *combo box* offers a user a way to select from a limited set of choices. Combo boxes can offer choices without taking up much room on the interface. The user simply clicks the combo box arrow to display additional choices. The LatinPlantNames application allows the user to select a plant name from a combo box:



The swing package includes the `JComboBox` class for creating combo boxes:

```
Class JComboBox (javax.swing.JComboBox)
Methods
JComboBox(Object[] items)
 creates a JComboBox object that contains the
 items from the items array, which must be an
 array of objects.
setSelectedIndex(int index)
 makes the item at index index the selected
 item.
getSelectedItem()
 returns the String corresponding to the selected
 JComboBox item.
setEditable(boolean)
 allows text to be typed in the combo box when
 true is the boolean argument.
addActionListener(Object)
 adds an object that listens for the user to select
 an item from this component's list.
```

### JComboBox event

Handling an event from a `JComboBox` requires two lines of code that are similar to:

```
JComboBox comboBox = (JComboBox) event.getSource();
String itemName = (String) comboBox.getSelectedItem();
```

The first statement determines the source of the action event and then the second statement determines which item has been selected.

The LatinPlantNames application code includes a JComboBox object:

```
import javax.swing.*;
import java.awt.*;
import java.awt.event.*;

public class LatinPlantNames implements ActionListener {
 JFrame frame;
 JPanel contentPane;
 JComboBox plantNames;
 JLabel plantListPrompt, latinName;

 public LatinPlantNames(){
 /* Create and set up the frame */
 frame = new JFrame("LatinPlantNames");
 frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);

 /* Create a content pane with a BoxLayout and
 empty borders */
 contentPane = new JPanel();
 contentPane.setLayout(new BoxLayout(contentPane,
 BoxLayout.PAGE_AXIS));
 contentPane.setBorder(BorderFactory.createEmptyBorder
 (10, 10, 10, 10));

 /* Create a combo box and a descriptive label */
 plantListPrompt = new JLabel("Select a plant name: ");
 plantListPrompt.setAlignmentX(JLabel.LEFT_ALIGNMENT);
 contentPane.add(plantListPrompt);

 String[] names = {"basil", "lavender", "parsley",
 "peppermint", "saffron", "sage"};
 plantNames = new JComboBox(names);
 plantNames.setAlignmentX(JComboBox.LEFT_ALIGNMENT);
 plantNames.setSelectedIndex(0);
 plantNames.addActionListener(this);
 contentPane.add(plantNames);

 /* Create and add a label that will display the
 Latin names */
 latinName = new JLabel("Ocimum");
 latinName.setBorder(BorderFactory.createEmptyBorder
 (20, 0, 0, 0));
 contentPane.add(latinName);

 /* Add content pane to frame */
 frame.setContentPane(contentPane);

 /* Size and then display the frame. */
 frame.pack();
 frame.setVisible(true);
 }
}
```

```

 /**
 * Handle a selection from the combo box
 * pre: none
 * post: The Latin name for the selected plant
 * has been displayed.
 */
 public void actionPerformed(ActionEvent event) {
 JComboBox comboBox = (JComboBox)event.getSource();
 String plantName = (String)comboBox.getSelectedItem();

 if (plantName == "basil") {
 latinName.setText("Ocimum");
 } else if (plantName == "lavender") {
 latinName.setText("Lavandula spica");
 } else if (plantName == "parsley") {
 latinName.setText("Apium");
 } else if (plantName == "peppermint") {
 latinName.setText("Mentha piperita");
 } else if (plantName == "saffron") {
 latinName.setText("Crocus");
 } else if (plantName == "sage") {
 latinName.setText("Salvia");
 }
 }
}

```

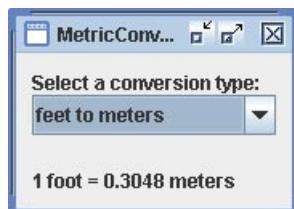
*...runGUI() and main() method of LatinPlantNames code*

The LatinPlantNames application displays the following output after sage has been selected:



## Review: MetricConversion

Create a MetricConversion application that allows the user to select a type of conversion from a combo box and then the corresponding formula is displayed in a label. To convert from the length measurement inches to centimeters, the formula is 1 inch = 2.54 centimeters. The formula 1 foot = 0.3048 meters converts the distance measurement feet to meters. The volume measurement gallon is converted to liters with the formula 1 gallon = 4.5461 liters. The formula 1 pound = 0.4536 kilograms converts the mass measurement pound to kilograms. The application interface should look similar to the following after the user has selected feet to meters:



# Changing Colors

Swing components have methods for changing their colors. For example, the content pane can be green, buttons can be magenta, combo boxes can display text in pink. When making color choices, keep the end user in mind because colors can give an application a fun and exciting look or completely turn users away.

## Color class

The java.awt package includes the Color class with numerous color constant members. The following methods, in the Swing component classes, can be used to change the background and foreground colors of the components:

`setBackground(Color.constant)`

sets the background color of a component to constant from the Color class.

`setForeground(Color.constant)`

sets the foreground color of a component to constant from the Color class.

How the color change affects the component varies. For a JLabel, the foreground color refers to the color of the text. For a JComboBox, the foreground color refers to the color of the text in the list.

The ColorDemo application demonstrates the color possibilities for components. The application GUI and the code, except for the runGUI() and main() methods, follow:



```
import javax.swing.*;
import java.awt.*;
import java.awt.event.*;

public class ColorDemo implements ActionListener {
 JFrame frame;
 JPanel contentPane;
 JTextField name;
 JButton displayMessage;
 JLabel textFieldPrompt, hello;

 public ColorDemo(){
 /* Create and set up the frame */
 frame = new JFrame("ColorDemo");
 frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);

 /* Create a content pane with a BoxLayout
 and empty borders */
 contentPane = new JPanel();
 contentPane.setBorder(BorderFactory.createEmptyBorder(
 10, 10, 10, 10));
 contentPane.setBackground(Color.white);
 contentPane.setLayout(new GridLayout(0, 2, 5, 10));
 }

 public void actionPerformed(ActionEvent e) {
 if (e.getSource() == displayMessage) {
 hello.setText("Hello " + name.getText());
 }
 }
}
```

```

/* Create a text field and a descriptive label */
textFieldPrompt = new JLabel("Type your name: ");
textFieldPrompt.setForeground(Color.red);
contentPane.add(textFieldPrompt);

name = new JTextField(10);
name.setBackground(Color.pink);
name.setForeground(Color.darkGray);
contentPane.add(name);

/* Create a Display Message button */
displayMessage = new JButton("Display Message");
displayMessage.setBackground(Color.yellow);
displayMessage.setForeground(Color.blue);
displayMessage.addActionListener(this);
contentPane.add(displayMessage);

/* Create a label that will display a message */
hello = new JLabel(" ");
hello.setForeground(Color.green);
contentPane.add(hello);

/* Add content pane to frame */
frame.setContentPane(contentPane);

/* Size and then display the frame. */
frame.pack();
frame.setVisible(true);
}

/**
 * Handle a the button click
 * pre: none
 * post: A message has been displayed.
 */
public void actionPerformed(ActionEvent event) {
 String text = name.getText();

 hello.setText("Hello " + text);
}

```

*...runGUI() and main() method of ColorDemo code*

## Adding Images

GIF, JPG

Images can make an application more informative, easier to use, and fun. Labels and buttons are often used to display an image, but many Swing components support images. Images that are GIF and JPG format work best. Unless a different path is specified in the application code, the image files must be in the same location as the compiled code.

The JLabel class includes a constructor and a method for displaying images in a label:

Class **JLabel** (`javax.swing.JLabel`)

Constructor/Method

`JLabel(ImageIcon pic)`

creates a JLabel object containing `pic`.

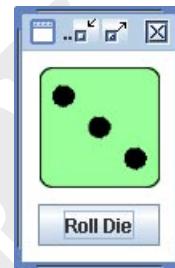
`setIcon(ImageIcon pic)`

sets the JLabel to contain `pic`.

The JButton class includes a constructor and a method for displaying images in a button:

```
Class JButton (javax.swing.JButton)
Constructor/Method
JButton(String str, ImageIcon pic)
 creates a JButton object containing the text str
 and the image pic.
JButton(ImageIcon pic)
 creates a JButton object containing the image
 pic.
setIcon(ImageIcon pic)
 sets the JButton to contain pic.
```

The Roll application displays a die face. The user can click Roll Die to “roll the die” and display the outcome of the roll. The application GUI and the code, except for the runGUI() and main() methods, follow:



```
import javax.swing.*;
import java.awt.*;
import java.awt.event.*;
import java.util.Random;

public class Roll implements ActionListener {
 JFrame frame;
 JPanel contentPane;
 JButton rollDie;
 JLabel dieFace;

 public Roll(){
 /* Create and set up the frame */
 frame = new JFrame("Roll");
 frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);

 /* Create a content pane with a BoxLayout and
 * empty borders */
 contentPane = new JPanel();
 contentPane.setBorder(BorderFactory.createEmptyBorder(
 10, 10, 10, 10));
 contentPane.setBackground(Color.white);
 contentPane.setLayout(new BoxLayout(contentPane,
 BoxLayout.PAGE_AXIS));

 /* Create a label that shows a die face */
 dieFace = new JLabel(new ImageIcon("die3.gif"));
 dieFace.setAlignmentX(JLabel.CENTER_ALIGNMENT);
 dieFace.setBorder(BorderFactory.createEmptyBorder(
 0, 0, 10, 0));
 contentPane.add(dieFace);
 }

 public void actionPerformed(ActionEvent e) {
 // Roll the die
 Random rand = new Random();
 int value = rand.nextInt(6) + 1;
 dieFace.setIcon(new ImageIcon("die" + value + ".gif"));
 }
}
```

```

 /* Create a Roll Die button */
 rollDie = new JButton("Roll Die");
 rollDie.setAlignmentX(JButton.CENTER_ALIGNMENT);
 rollDie.addActionListener(this);
 contentPane.add(rollDie);

 /* Add content pane to frame */
 frame.setContentPane(contentPane);

 /* Size and then display the frame. */
 frame.pack();
 frame.setVisible(true);
 }

 /**
 * Handle a button click
 * pre: none
 * post: A die has been rolled. Matching image shown.
 */
 public void actionPerformed(ActionEvent event) {
 Random rand = new Random();
 int newRoll;

 newRoll = rand.nextInt(6) + 1;
 if (newRoll == 1) {
 dieFace.setIcon(new ImageIcon("die1.gif"));
 } else if (newRoll == 2) {
 dieFace.setIcon(new ImageIcon("die2.gif"));
 } else if (newRoll == 3) {
 dieFace.setIcon(new ImageIcon("die3.gif"));
 } else if (newRoll == 4) {
 dieFace.setIcon(new ImageIcon("die4.gif"));
 } else if (newRoll == 5) {
 dieFace.setIcon(new ImageIcon("die5.gif"));
 } else if (newRoll == 6) {
 dieFace.setIcon(new ImageIcon("die6.gif"));
 }
 }
}

```

An image must be an object of the `ImageIcon` class for use in a Swing GUI. The `ImageIcon` class, from the `java.swing` package, has a constructor that accepts a file name as an argument and then converts that file to an `ImageIcon` object.

## Review: Roll

Modify the Roll application to roll two dice. Include an image for each die. Change the colors of the components to be more exciting, while still allowing the user to easily read the text on the button and to see the die images. The die images are name die1.tif, die2.tif, die3.tif, die5.tif, and die6.tif and are supplied as data files for this text.

## Using Nested Classes to Handle Events

A GUI can quickly become complex, as a combination of buttons, text fields, and other components that must handle events are added. When a variety of components are on a single interface, separate actionPerformed() methods should handle their events.

Up to this point, an instance of the controlling class (`this`) implemented an actionPerformed() method. This single method was used to handle events for every component on the GUI. This was sufficient for a simple GUI. However, a GUI with more than one type of component responding to an event should have multiple listeners. One way to implement multiple listeners in a single application is to create each listener from a nested class.

**TIP** A nested class is also called an inner class.

### outer class

A *nested class* is a class within a class. A nested class is a member of the class it is within. As a class member, it has access to all the other members of the class, including private member variables and methods. A class that contains a class member is called an *outer class*. The Semester Stats application uses two nested classes to respond to events:

```
import javax.swing.*;
import java.awt.*;
import java.awt.event.*;

public class SemesterStats {
 JFrame frame;
 JPanel contentPane;
 JLabel prompt1, prompt2, prompt3, stat;
 JTextField grade1, grade2, grade3;
 JButton avgButton, minButton, maxButton;

 public SemesterStats(){
 /* Create and set up the frame */
 frame = new JFrame("Semester Stats");
 frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);

 /* Create content pane with a GridLayout and empty borders */
 contentPane = new JPanel();
 contentPane.setLayout(new GridLayout(0, 2, 10, 5));
 contentPane.setBorder(BorderFactory.createEmptyBorder(
 10, 10, 10, 10));

 /* Create and add a prompt and then a text field */
 prompt1 = new JLabel("Enter the first grade: ");
 contentPane.add(prompt1);

 grade1 = new JTextField(10);
 contentPane.add(grade1);

 /* Create and add a second prompt and then a text field */
 prompt2 = new JLabel("Enter the second grade: ");
 contentPane.add(prompt2);

 grade2 = new JTextField(10);
 contentPane.add(grade2);

 /* Create and add a third prompt and then a text field */
 prompt3 = new JLabel("Enter the third grade: ");
 contentPane.add(prompt3);

 grade3 = new JTextField(10);
 contentPane.add(grade3);
```

```

/* Create and add button that will display the average grade */
avgButton = new JButton("Average");
avgButton.addActionListener(new AvgListener());
contentPane.add(avgButton);

/* Create and add button that will display the min grade */
minButton = new JButton("Min");
minButton.setActionCommand("Min");
minButton.addActionListener(new MinMaxListener());
contentPane.add(minButton);

/* Create and add button that will display the max grade */
maxButton = new JButton("Max");
maxButton.setActionCommand("Max");
maxButton.addActionListener(new MinMaxListener());
contentPane.add(maxButton);

/* Create and add a label that will display stats */
stat = new JLabel(" ");
stat.setBorder(BorderFactory.createEmptyBorder(10, 0, 10, 0));
contentPane.add(stat);

/* Add content pane to frame */
frame.setContentPane(contentPane);

/* Size and then display the frame. */
frame.pack();
frame.setVisible(true);
}

class AvgListener implements ActionListener {

 /**
 * Handle Average button click event
 * pre: none
 * post: The grade average has been calculated and displayed.
 */
 public void actionPerformed(ActionEvent event) {
 double avgGrade;
 String g1 = grade1.getText();
 String g2 = grade2.getText();
 String g3 = grade3.getText();

 avgGrade = (Double.parseDouble(g1) + Double.parseDouble(g2) +
 Double.parseDouble(g3))/3;
 stat.setText(Double.toString(avgGrade));
 }
}

```

```

class MinMaxListener implements ActionListener {

 /**
 * Handles the Min and Max button click events
 * pre: none
 * post: The minimum or maximum grade has been
 * determined and displayed.
 */
 public void actionPerformed(ActionEvent event) {
 String eventName = event.getActionCommand();
 double minGrade = 999;
 double maxGrade = 0;
 double[] grades = new double[3];

 grades[0] = Double.parseDouble(grade1.getText());
 grades[1] = Double.parseDouble(grade2.getText());
 grades[2] = Double.parseDouble(grade3.getText());

 if (eventName.equals("Min")) {
 for (int i = 0; i < 3; i++) {
 if (minGrade > grades[i]) {
 minGrade = grades[i];
 }
 }
 stat.setText(Double.toString(minGrade));
 } else if (eventName.equals("Max")) {
 for (int i = 0; i < 3; i++) {
 if (maxGrade < grades[i]) {
 maxGrade = grades[i];
 }
 }
 stat.setText(Double.toString(maxGrade));
 }
 }

 /**
 * Create and show the GUI.
 */
 private static void runGUI() {
 JFrame.setDefaultLookAndFeelDecorated(true);

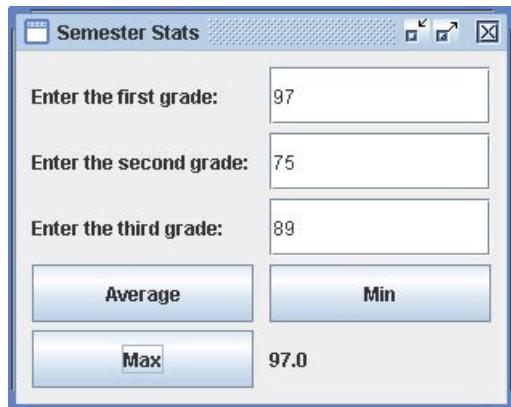
 SemesterStats myGrades = new SemesterStats();
 }

 public static void main(String[] args) {
 /* Methods that create and show a GUI should be
 run from an event-dispatching thread */
 javax.swing.SwingUtilities.invokeLater(new Runnable() {
 public void run() {
 runGUI();
 }
 });
 }
}

```

One class (AvgListener) was used to implement a listener for the Average button and a second class (MinMaxListener) implements a listener for the Min and Max buttons. These buttons were combined into one listener because their algorithms closely match.

The SemesterStats application displays output similar to:



## Chapter 11 Case Study

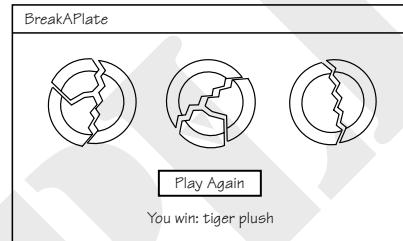
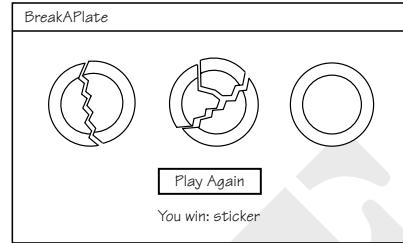
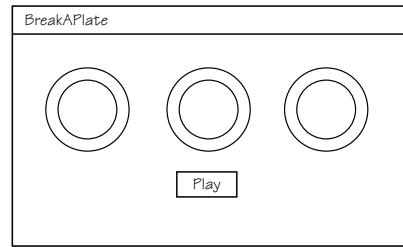
In this case study, a Swing GUI will be created for an application that plays a carnival game called Break-A-Plate. The Break-A-Plate game allows a player to try to break all three plates. If all three plates are broken, a first prize is awarded, otherwise, a consolation prize is awarded.

### BreakAPlate Specification

The BreakAPlate application displays three unbroken plates at the start. Clicking Play plays the game, displays broken plates, and displays the prize won. If all three plates are broken, a tiger plush first prize is awarded. If less than three plates are broken, a sticker consolation prize is awarded. At the end of a game the Play button changes to Play Again. Clicking Play Again displays a set of unbroken plates and the button changes back to Play allowing the user to play repeatedly. The application ends when the user closes the window.

The BreakAPlate game uses random numbers to determine if a player has broken all three plates. When three 1s are generated by the random number generator then the application displays three broken plates. If zero, one, or two ones are generated, then the application displays two broken plates indicating a loss.

The BreakAPlate interface should be a GUI that includes a label for displaying the image of the plates, a button for allowing the user to play or play again, and a label for displaying the the prize won. The BreakAPlate GUI should look similar to the following before a game is played, after a losing game has been played, and after a winning game has been played:



The BreakAPlate algorithm:

1. When a game is played, generate three random numbers between 0 and 1.
2. If three ones are generated, display three broken plates and the names of the first prize. Otherwise, display two broken plates and the name of the consolation prize.

### BreakAPlate Code Design

The BreakAPlate application simulates a game booth at a carnival. The game can therefore be modeled with a GameBooth object. The GameBooth class was created in Chapter 8 and contains the following methods:

**TIP** Refer to Chapter 8 for the GameBooth code.

Class GameBooth (Lawrenceville Press)

Constructor/Methods

GameBooth(int cost, String p1, String p2)

creates a GameBooth object that charges `cost` amount to play, awards a first prize `p1`, and a consolation prize `p2`. If there is no charge for the game, or the charge is not a consideration, then 0 should be the argument for `cost`.

`start()`

simulates a game that allows the player three plays. If the player succeeds all three times, then the name of the first prize is returned. Otherwise, the name of the consolation prize is returned.

`getCost()`

returns the cost of the game.

The cost of the game is not a factor in this application, so 0 will be the argument for the `cost` parameter in the constructor, and the `getCost()` method will not be needed.

Based on the algorithm and the `GameBooth` class, the `BreakAPlate` `actionPerformed()` method pseudocode looks similar to:

```
String eventName = event.getActionCommand();
String prize;

if (Play) {
 prize = breakAPlate.start();
 if (prize is tiger plush) {
 display all broken plates;
 } else if (prize is sticker)) {
 display two broken plates
 }
 display prize won
 change button to Play Again
} else if (Play Again) {
 display unbroken plates
 clear prize won text
 change button to Play
```

### BreakAPlate Implementation

The `BreakAPlate` implementation involves creating the `BreakAPlate.java` file and adding the `GameBooth.java` file to the project.

The `BreakAPlate` application is implemented below:

```
/*
 * BreakAPlate.
 */
import javax.swing.*;
import java.awt.*;
import java.awt.event.*;

public class BreakAPlate implements ActionListener {
 static final String FIRST_PRIZE = "tiger plush";
 static final String CONSOLATION_PRIZE = "sticker";
 JFrame frame;
 JPanel contentPane;
 JButton play;
 JLabel plates, prizeWon;
 GameBooth breakAPlate;

 public BreakAPlate(){
 /* initialize game booth and player */
 breakAPlate = new GameBooth(0, FIRST_PRIZE, CONSOLATION_PRIZE);

 /* Create and set up the frame */
 frame = new JFrame("BreakAPlate");
 frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);

 /* Create a content pane with a BoxLayout and empty borders */
 contentPane = new JPanel();
 contentPane.setBorder(BorderFactory.createEmptyBorder(20, 20, 20, 20));
 contentPane.setBackground(Color.white);
 contentPane.setLayout(new BoxLayout(contentPane, BoxLayout.PAGE_AXIS));
```

```

/* Create a label that shows the start of the game */
plates = new JLabel(new ImageIcon("plates.gif"));
plates.setAlignmentX(JLabel.CENTER_ALIGNMENT);
plates.setBorder(BorderFactory.createEmptyBorder(10, 10, 20, 10));
contentPane.add(plates);

/* Create a Play button */
play = new JButton("Play");
play.setActionCommand("Play");
play.setAlignmentX(JButton.CENTER_ALIGNMENT);
play.addActionListener(this);
contentPane.add(play);

/* Create a label that will show prizes won */
prizeWon = new JLabel(" ");
prizeWon.setAlignmentX(JLabel.CENTER_ALIGNMENT);
prizeWon.setBorder(BorderFactory.createEmptyBorder(20, 0, 0, 0));
contentPane.add(prizeWon);

/* Add content pane to frame */
frame.setContentPane(contentPane);

/* Size and then display the frame. */
frame.pack();
frame.setVisible(true);
}

/**
 * Handle the button click
 * pre: none
 * post: The appropriate image and message are displayed.
 */
public void actionPerformed(ActionEvent event) {
 String eventName = event.getActionCommand();
 String prize;

 if (eventName == "Play") {
 prize = breakAPlate.start();
 if (prize.equals(FIRST_PRIZE)) {
 plates.setIcon(new ImageIcon("plates_all_broken.gif"));
 } else if (prize.equals(CONSOLATION_PRIZE)) {
 plates.setIcon(new ImageIcon("plates_two_broken.gif"));
 }
 prizeWon.setText("You win: " + prize);
 play.setText("Play Again");
 play.setActionCommand("Play Again");
 } else if (eventName == "Play Again") {
 plates.setIcon(new ImageIcon("plates.gif"));
 prizeWon.setText(" ");
 play.setText("Play");
 play.setActionCommand("Play");
 }
}

```

```

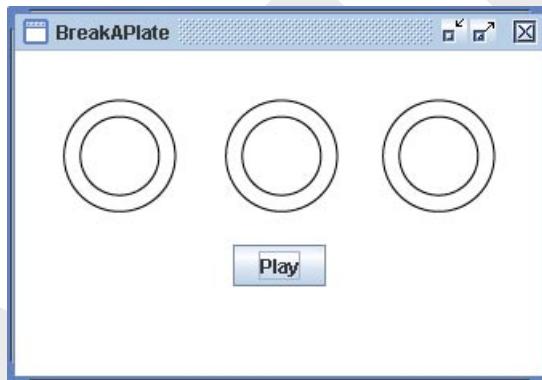
/**
 * Create and show the GUI.
 */
private static void runGUI() {
 JFrame.setDefaultLookAndFeelDecorated(true);

 BreakAPlate carnivalGame = new BreakAPlate();
}

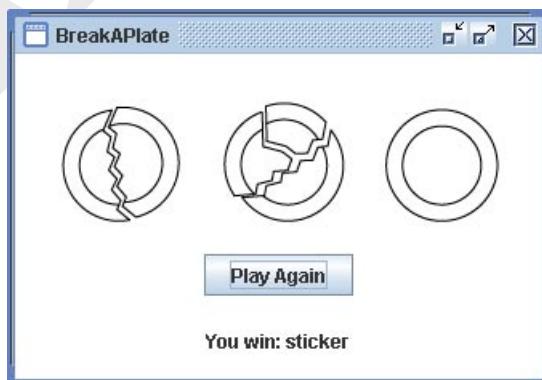
public static void main(String[] args) {
 /* Methods that create and show a GUI should be
 run from an event-dispatching thread */
 javax.swing.SwingUtilities.invokeLater(new Runnable() {
 public void run() {
 runGUI();
 }
 });
}
}

```

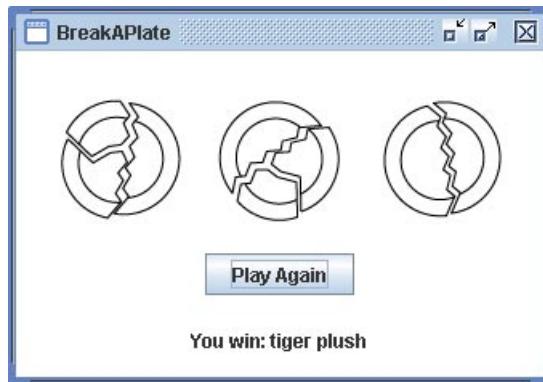
Running the BreakAPlate application displays a GUI similar to:



When **Play** is clicked, the user either wins or loses. The output below shows a losing game:



The application GUI below shows a winning game:

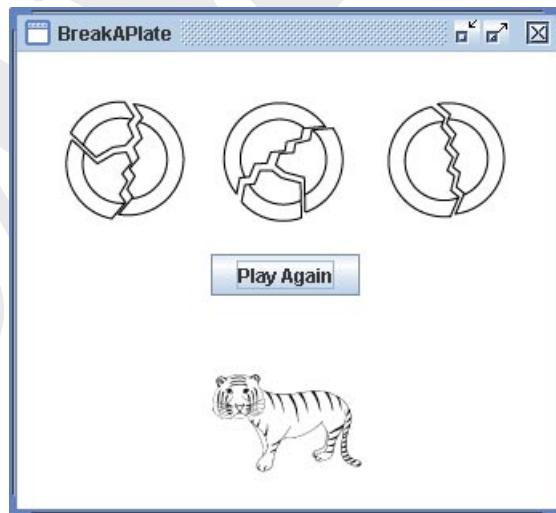


### BreakAPlate Testing and Debugging

The application should be tested by playing several games, making sure that the correct prize is named and that the buttons and images change appropriately.

## Review: BreakAPlate

Modify the BreakAPlate application to display a picture of the prize won rather than text naming the prize. The tiger\_plush.gif, sticker.gif, and placeholder.gif are supplied as data files for this task. The placeholder.gif file is a white square that is the same size as the tiger\_plush and sticker images. The placeholder.gif file should be displayed in the label at the start of each game. The modified BreakAPlate interface should look similar to the following after the user has played a winning game:



## Chapter Summary

This chapter introduced graphical user interfaces that use the Swing API. The Java swing package contains many component classes, including JFrames, JPanel, JLabels, JButton, JComboBoxes, and JTextField.

Applications with a GUI are event-driven. The GUI must be run from an event-dispatching thread. A GUI application responds to interactions from the user called events. An event executes a method called an event handler. A Swing event handler is also called an action event handler.

A frame is a container for content panels. A commonly used content panel is the JPanel component. A JPanel can contain other components such as labels and buttons. A label is a component that does not receive events. A button is a commonly used component for accepting input from the user.

Only components with a listener object can execute an event handler. A listener executes the actionPerformed() event handler, passing it the an ActionEvent object that contains the action command describing the event.

The layout of components in a JPanel can be controlled with layout manager and the use of borders and alignment. The FlowLayout, BoxLayout, and GridLayout are the three managers covered in this chapter. The placement of components within a layout can be controlled further with empty borders for padding and using alignment.

The text field component allows a user to type information into the interface. The information typed into a text field is a string. The Integer and Double classes include class methods for converting information to numeric data. The label component requires a string when setting the text. The Integer and Double classes also provide the toString() method for converting numeric data to a String.

Combo boxes allow the user to select from a limited set of choices. A combo box does not take up much space and displays a list of choices when its arrow button is clicked.

Most of the components include methods for setting the background and foreground colors. Color can make an application easier to use and more interesting, but should be selected with the user in mind.

GIF and JPG images can be included in an application GUI. A label or a button is commonly used to display an image.

Nested classes are used to implement multiple event handlers. Nested classes, like any other member of a class, have access to other members of the class, including private variables and method members. A class that contain a class member is called an outer class.

## Vocabulary

**Action command** A string describing an event.

**Alignment** The placement of components within a layout.

**BoxLayout manager** A layout manager that places components one after the other in a column.

**Button** A GUI component that the user can click.

**Combo box** A GUI component that offers a user a way to select from a limited set of choices.

**Container** A component that holds and displays all the other components of a GUI.

**Content frame** A top-level container.

**Event** A user interaction with an application's GUI.

**Event-driven application** An application that responds to events.

**Event handler** A method that executes in response to an event.

**FlowLayout manager** A layout manager that places components one next to the other in a row.

**Frame** A GUI window that contains a border, title, and maximize, minimize, and close buttons.

**GridLayout manager** A layout manager that places components in a grid of rows and columns.

**Label** A GUI component that displays text or an image and does not interact with the user.

**Layout** The arrangement of components.

**Layout manager** Used to specify the order of components on a content pane.

**Listener** An object that listens for action events.

**Nested class** A class that is a member of another class. A class within a class.

**Outer class** A class that contains a class member.

**Text field** A GUI component that allows a user to enter information at run time.

**Thread** A process that runs sequentially from start to finish.

**ActionListener** The `java.awt.event` interface that contains the `actionListener()` method.

**actionPerformed()** A method that is implemented to respond to events. This method is the only method in the `ActionListener` interface.

**BorderFactory** The `java.lang` class with class methods for creating a border object.

**BoxLayout** A `javax.swing` class for setting the layout of a content pane.

**Color** The `java.awt` class that contains constants for changing component colors.

**Double** A `java.lang` class for converting numbers between numeric and text data.

**GridLayout** A `java.awt` class for setting the layout of a content pane.

**ImageIcon** A `java.swing` class for converting an image, such as a GIF or JPG, to an `ImageIcon` object.

**Integer** A `java.lang` class for converting numbers between numeric and text data.

**java.awt** The package containing the `GridLayout` class and `Color` class constants.

**java.awt.event** The package containing the `ActionListener` interface.

**java.swing** The package containing the Swing API classes.

**JButton** A `java.swing` class for creating a button in a GUI. The class includes methods for adding text or images to the label.

**JComboBox** A `java.swing` class for creating a combo box in a GUI.

**JFrame** A `java.swing` class for creating a window, also called a frame, in a GUI.

**JLabel** The `java.swing` class for creating a label in a GUI. The class includes methods for adding text or images to the label.

**JPanel** The `java.swing` class for creating a content panel for a frame. The class includes methods for adding and removing components.

**JTextField** The `java.swing` class for creating a text field.

**FlowLayout** A `javax.swing` class for setting the layout of a content pane.

**Swing API** A part of the Java Foundation Classes that contains numerous components for creating GUIs.

**this** The keyword for indicating an object itself.

## Critical Thinking

1. Explain the difference between an event-driven application and a console-based application.
2. Explain how code is executed in an event-driven application.
3. Can components be added directly to a frame? Explain.
4. Can a label respond to events? Explain.
5. Why do you think a GUI needs to be run from an event-dispatching thread?
6. What is the difference between a label and a button?
7.
  - a) What does `this` indicate when used as the argument for the `addActionListener()` method?
  - b) What must the object listening for an event contain?
8. List three ways to control the layout of a content pane.
9. What type of borders are used to add padding around components?
10. List three layout managers and explain how each arranges the components on a content pane.
11. Which class is used to return an object for the `setBorder()` method?
12. Are borders for padding necessary when the `GridLayout` manager is used? Explain.
13. What must first be done with numeric data typed in a text field before it can be used in a calculation?
14. What is the value of `num1` in the last statement below?

```
double num1;
Double num2 = new Double(3);
String num3 = "5";
num1 = num2.doubleValue() +
 Double.valueOf(num3).doubleValue();
```
15. An application prompts a user to select a name from a list of six names. Which is a better component choice: a text field or a combo box? Explain.
16. Would white text on a pink background be a good color combination for a GUI? Why or why not?
17. What image types are supported in a Swing GUI?
18. Which components are often used to display an image?
19. What must an image be converted to in order to be displayed by a Swing component?

### True/False

20. Determine if each of the following are true or false. If false, explain why.
  - a) `JFrame` is a class in the `javax.swing` package.
  - b) A button click is an event handler.
  - c) Labels can be changed by the user.
  - d) A `JFrame` object uses a content pane to hold GUI components.
  - e) The index value for the first component on a content pane is 1.
  - f) The `JLabel` class constant `LEADING` indicates right alignment.
  - g) A thread is a sequential process that runs from start to finish.
  - h) Swing components use listeners to determine if an event has occurred.
  - i) A class that uses a listener must implement an `ActionListener` class.
  - j) An empty border indicates that there is no space around a component.
  - k) The `FlowLayout` manager places components one after the other in a column, with one column per line.
  - l) All components on a GUI must have the same alignment.
  - m) The class `content PAGE_AXIS` specifies that components should be arranged in a vertical line.
  - n) The `JLabel` `setAlignmentX()` method is used to specify the horizontal alignment of the components within the layout.

- o) Code using the `BoxLayout` manager requires an `import java.awt.*` statement.
- p) Information is entered into a text field at run time.
- q) A text field can only accept numeric data.
- r) The `JLabel` foreground color refers to the text color.
- s) A Swing GUI can have only one listener.
- t) A nested class has access to the `private` variable members of the outer class.

## Exercises

### Exercise 1

### LocalBankGUI

Create LocalBankGUI application that implements a GUI for the Local Bank case study in Chapter 9.

### Exercise 2

### TicTacToeGUI

Create a TicTacToeGUI application that allows two players to play a computerized tic-tac-toe game. Refer to the TicTacToe application presented in Chapter 9. The TTT class code will need to be modified for the GUI version of the application. Use a button for each “box” in the tic-tac-toe board.

### Exercise 3

### PhotoAlbum

Create a PhotoAlbum application that displays a new picture each time Next is clicked. Use the grayangel.jpg, scorpionfish.jpg, sponges.jpg, and starfish.jpg files supplied as data files for this text. The application should allow the user to continuously cycle through the images.

### Exercise 4

### Clacker

In the game Clacker, the numbers 1 through 12 are initially displayed. The player throws two dice and may cover the number representing the total or the two numbers on the dice. For example, for a throw of 3 and 5, the player may cover the 3 and the 5 or just the 8. Play continues until all the numbers are covered. The goal is to cover all the numbers in the fewest rolls.

Create a Clacker application that displays 12 buttons numbered 1 through 12. Each of these buttons can be clicked to “cover” it. A covered button displays nothing. Another button labeled Roll can be clicked to roll the dice. Include labels to display the appropriate die images for each roll. Another label displays the number of rolls taken. A New Game button can be clicked to clear the labels and uncover the buttons for a new game.

### Exercise 5

### LifeGUI

Create a LifeGUI application that is based on the Life application created in Chapter 10, Exercise 14. The  $20 \times 20$  grid should be buttons that initially display all 0s. To select the live cells for the first day, the user clicks the buttons in the positions of live cells. When clicked, a button changes from displaying a 0 to displaying an X. A Next button below the grid can be clicked repeatedly to display the next generations until the user quits or there are no more live cells.

SAMPLE

# Chapter 12

## Files and Exception Handling

**F**iles are used by many applications for storing and retrieving data. In this chapter, sequential file access, including object serialization will be discussed. Exception handling will also be explained.

### What is a File?

Up to this point, the applications created in this text have stored data in the computer's memory. However, storage in memory is available only when the computer is on and an application is running. A *file* is a collection of related data stored on a persistent medium such as a hard disk or a CD. *Persistent* simply means lasting.

*persistent*

Files often store data used by an application. Files are also used to store the data generated by an application. In either case, a file is separate from the application accessing it and can be read from and written to by more than one application. Most applications require access to one or more files on disk.

### The File Classes

*java.io*

The File class, part of the *java.io* package, is used for creating an object that represents a file. A File object can be used to create a new file, test for the existence of a file, and delete a file. Some of the File class methods include:

Class **File** (*java.io*)

Constructor/Methods

`File(String f)` creates a File object that refers to the file *f*.

`createNewFile()`

creates a new file using the file name specified in the constructor if the file does not already exist. Returns `true` if the file is created, `false` otherwise. This method throws an *IOException* exception if the file cannot be created.

`delete()`

permanently deletes the file represented by the File object. Returns true if the file is deleted, false otherwise.

`exists()`

Returns `true` if the file represented by the File object exists, `false` otherwise.

The application below checks for the existence of a file:

```
import java.io.*;

public class TestFiles {

 public static void main(String[] args) {
 File textField = new File("c:\\temp\\supplies.txt");
 if (textField.exists()) {
 System.out.println("File already exists.");
 } else {
 System.out.println("File does not exist.");
 }
 }
}
```

The name of a file is specified as a String. If a path is included in the file name, escape sequences (\\) must be used to separate the drive, folder, and file names.

## Review: MyFile – part 1 of 2

Create a MyFile application that prompts the user for the name of a file and then displays a message that indicates whether the files exists or not. Note that if the user types in a full path, any single backslashes (\) will need to be replaced with an escape sequence(\\) in order to create a new File object.

## Handling Exceptions

### *exception*

An *exception* is an error affecting program execution. If an exception is not taken care of, or *handled*, the application abruptly terminates. Although many types of exceptions may still require program termination, an exception handler can allow an application to terminate gracefully by providing the user with an informative error message.

### *exception handler*

An *exception handler* is a block of code that performs an action when an exception occurs. The try-catch-finally statement can be used to write an exception handler. It takes the form:

```
try {
 <statements>
} catch (exception err_code) {
 <statements>
} ...additional catch clauses
} finally (exception err_code) {
 <statements>
```

The *try* statements are the statements that could possibly generate an exception. The *catch* clause waits for the exception matching the *exception* parameter and then executes its code. If more than one type of exception is possible from the statements in the *try* clause, then a separate *catch* should be written for each type of exception. The *finally* clause is optional and executes its statements regardless of what happens in the *try-catch* portion of the error handler.

### **IOException throw**

An exception handler is required when calling certain methods. For example, the `createNewFile()` method in the `File` class generates an `IOException` exception when the specified file name cannot be used to create a file. The `createNewFile()` method includes code to *throw*, or generate, an exception object if it cannot complete its task.

The modified `TestFiles` application checks for the existence of a file before creating a new one:

```
import java.io.*;

public class TestFiles {

 public static void main(String[] args) {
 File textFile = new File("c:\\supplies.txt");
 if (textFile.exists()) {
 System.out.println("File already exists.");
 } else {
 try {
 textFile.createNewFile();
 System.out.println("New file created.");
 } catch (IOException e) {
 System.out.println("File could not be created.");
 System.err.println("IOException: " + e.getMessage());
 }
 }
 }
}
```

#### **The Exception Stack**

When an exception is thrown, the current block of code is first checked for an exception handler. Next, the calling method is checked for a handler, and so on until the Java interpreter is reached.

#### **err stream**

An exception, such as `IOException`, is an object of the `Throwable` class. `Throwable` objects have a `getMessage()` member that returns a `String` containing information about the exception. The *err stream* is used for displaying error messages on the screen.

## **Review: MyFile – part 2 of 2**

Create a `MyFile` application that creates a file named `zzz.txt` and then displays a message indicating that the file has been created. The application should prompt the user to either keep or delete the file. If the file is deleted, a message should notify the user when the file has been successfully deleted.

**TIP** The `Scanner` class requires an `input stream`.

#### **file position**

#### **sequential file access**

## **The File Streams**

A file must be associated with a stream in order to perform operations such as reading the contents, writing over existing contents, and adding to the existing contents. A *stream* processes characters, and in Java, streams are implemented with classes.

The file stream keeps track of the *file position*, which is the point where reading or writing last occurred. File streams are used to perform *sequential file access*, with all the reading and writing performed one character after another or one line after another.

## Data Streams

A stream applies to data input/output in general. For example, memory, information sent to a printer, and data sent and received from an Internet site can all be streamed.

### *line terminator, end of file*

A stream can be thought of as a sequence of characters. For example, a file containing a list of names and scores may look like the following when viewed in a word processor:

Drew 84  
Tia 92

However, when thinking about file operations, the file should be visualized as a stream of data:

|   |   |   |   |  |   |   |    |    |   |   |   |  |   |   |    |    |    |
|---|---|---|---|--|---|---|----|----|---|---|---|--|---|---|----|----|----|
| D | r | e | w |  | 8 | 4 | Cr | Lf | T | i | a |  | 9 | 2 | Cr | Lf | -1 |
|---|---|---|---|--|---|---|----|----|---|---|---|--|---|---|----|----|----|

The carriage return character (Cr) followed by a line feed character (Lf) is called a *line terminator*. A -1 is the *end of file*.

## The FileReader and BufferedReader Classes

### *input file stream*

The FileReader and BufferedReader classes, both from the java.io package, are used together to read the contents of an existing file. The FileReader class is used to create an *input file stream*. Next, the BufferedReader class is used to read text from the stream. The following is a summary of the FileReader and BufferedReader classes:

#### Class FileReader (java.io)

##### Constructor/Method

FileReader(File fileName)

creates an input file stream for the File object. This constructor throws a FileNotFoundException exception if the file does not exist.

close()  
closes the input file stream. This method throws an IOException exception if the file cannot be closed.

#### Class BufferedReader (java.io)

##### Constructor/Methods

BufferedReader(Reader stream)

creates a buffered-input stream from stream. Reader is the FileReader superclass.

read()  
reads a single character from the input stream. This method throws an IOException exception if the stream cannot be read.

readLine()  
reads a line of text from the input stream. This method throws an IOException exception if the stream cannot be read.

close()  
closes the input file stream. This method throws an IOException exception if the stream cannot be closed.

**TIP** A buffer stores a large number of characters from the stream so that more than one character at a time can be read, such as in a readLine().

## Reading Characters

The read() method returns an int, which corresponds to a Unicode value. In Unicode, a space corresponds to 32, a tab to 9, carriage return to 13, and line feed to 10.

The application on the next page reads an existing file line-by-line to show the contents of the file:

```

import java.util.Scanner;
import java.io.*;

public class ReadFile {

 public static void main(String[] args) {
 File textFile = new File("wonder.txt");
 FileReader in;
 BufferedReader readfile;
 String lineOfText;

 try {
 in = new FileReader(textFile);
 readfile = new BufferedReader(in);
 while ((lineOfText = readfile.readLine()) != null) {
 System.out.println(lineOfText);
 }
 readfile.close();
 in.close();
 } catch (FileNotFoundException e) {
 System.out.println("File does not exist or could
 not be found.");
 System.err.println("FileNotFoundException: "
 + e.getMessage());
 } catch (IOException e) {
 System.out.println("Problem reading file.");
 System.err.println("IOException: " + e.getMessage());
 }
 }
}

```

The ReadFile application reads and displays the file contents within a `try`-`catch` statement because both the `FileReader` and `BufferedReader` constructors and methods throw exceptions if there is a problem reading the file. A `try` can have multiple `catch` statements. The `catch` statements are in the order that they may occur. For example, the `FileNotFoundException` is handled first because the `FileReader` object is created first in the `try` statement.

The `close()` methods are used to close the `FileReader` and `BufferedReader` streams. It is important that the streams be closed in the reverse order that they were opened.

The ReadFile application displays the following output when run:

```

The little girl shouted "Go, Wonder Horse, go!"
Her brother stared in disbelief as his toy horse began to fly.
Together they laughed while the horse flew around them.

```

## Review: Assignment

Create a Assignment application that reads and then displays the contents of a file containing instructions for this assignment. Use Notepad or some other word processor to create the file. Be sure that the file is saved as a Text file (TXT). The Assignment application will need to include the correct path to the location of the file. If a path is not specified, the file must be placed in the same folder as the Assignment executable file.

# Processing Numeric Data

A file on disk is a set of characters, even when the file contains numeric data, such as test scores. An application written to process numeric data from a file must convert the data after it is read. The Double and Integer classes include class methods for converting a string to a primitive data type:

Class Double (java.lang.Double)  
Method  
parseDouble(String text)  
returns the double value in the String text.

Class Integer (java.lang.Integer)  
Method  
parseInt(String text)  
returns the int value in the String text.

The AvgScore application reads tests scores that are stored one score per line in a text file and then reports the average:

## DAT Files

Text files that contain numeric data often have the file name extension .dat, also referred to as a DAT file.

```
import java.io.*;

public class AvgScore {

 public static void main(String[] args) {
 File dataFile = new File("scores.dat");
 FileReader in;
 BufferedReader readfile;
 String score;
 double avgScore;
 double totalScores = 0;
 int numScores = 0;

 try {
 in = new FileReader(dataFile);
 readfile = new BufferedReader(in);
 while ((score = readfile.readLine()) != null) {
 numScores += 1;
 System.out.println(score);
 totalScores += Double.parseDouble(score);
 }
 avgScore = totalScores / numScores;
 System.out.println("Average = " + avgScore);
 readfile.close();
 in.close();
 } catch (FileNotFoundException e) {
 System.out.println("File does not exist or could
 not be found.");
 System.err.println("FileNotFoundException: "
 + e.getMessage());
 } catch (IOException e) {
 System.out.println("Problem reading file.");
 System.err.println("IOException: " + e.getMessage());
 }
 }
}
```

The application produces the output:

```
88
92
76
95
67
82
91
Average = 84.42857142857143
```

## Review: Stats – part 1 of 2

Create a Stats application that reads names and scores from a data file named test1.dat, supplied with this text. The file contains a student name on one line followed by the student's test score on the next line. The Stats application should read and display each name and score. After all the scores have been displayed, the lowest score, highest score, and average score should be displayed.

*output file stream*

## The **FileWriter** and **BufferedWriter** Classes

The **FileWriter** and **BufferedWriter** classes, both from the `java.io` package, are used together to write data to a file. The **FileWriter** class is used to create an *output file stream*. A **BufferedWriter** class object is then used to send text to the stream. Some of the **FileWriter** and **BufferedWriter** classes methods include:

Class **FileWriter** (`java.io`)

Constructor/Method

```
FileWriter(File fileName, boolean append)
```

creates an input file stream for the `File` object. If `append` is true, then data written to the file will be added after existing data, otherwise the file will be overwritten. This constructor throws an `IOException` exception if the file cannot be created or opened.

`close()`

closes the output file stream. This method throws an `IOException` exception if the file cannot be closed.

When a **FileWriter** object is created, the file referenced by the `File` object is automatically overwritten unless the **FileWriter** object is set to append. In either case, if the file does not yet exist, a new one will be created. Caution must be used so that a file is not inadvertently overwritten.

## Class BufferedWriter (java.io)

### Constructor/Methods

`BufferedWriter(Writer stream)`

creates a buffered-writer stream from `stream`.  
Writer is the `FileWriter` superclass.

`newLine()`

writes a newline character to the output stream.  
This method throws an `IOException` exception  
if the stream cannot be written to.

`write(String str)`

writes the string `str` to the output stream. This  
method throws an `IOException` exception if the  
stream cannot be written to.

`write(char c)`

writes the character `c` to the output stream. This  
method throws an `IOException` exception if the  
stream cannot be written to.

`close()`

closes the output file stream. This method  
throws an `IOException` exception if the stream  
cannot be closed.

The `CreateDataFile` application prompts the user for names and scores  
and then writes them to a new file:

```
import java.io.*;
import java.util.Scanner;

public class CreateDataFile {

 public static void main(String[] args) {
 File dataFile = new File("StuScores.dat");
 FileWriter out;
 BufferedWriter writeFile;
 Scanner input = new Scanner(System.in);
 double score;
 String name;

 try {
 out = new FileWriter(dataFile);
 writeFile = new BufferedWriter(out);
 for (int i = 0; i < 5; i++) {
 System.out.print("Enter student name: ");
 name = input.nextLine();
 System.out.print("Enter test score: ");
 score = input.nextDouble();
 writeFile.write(name);
 writeFile.newLine();
 writeFile.write(String.valueOf(score));
 writeFile.newLine();
 }
 writeFile.close();
 out.close();
 System.out.println("Data written to file.");
 } catch (IOException e) {
 System.out.println("Problem writing to file.");
 System.err.println("IOException: " + e.getMessage());
 }
 }
}
```

Note that the application will overwrite the `StuScores.dat` file each time  
that it is run. The `CreateDataFile` application displays output similar to  
that shown on the next page:

```
Enter student name: Tyra
Enter test score: 98
Enter student name: Carmen
Enter test score: 83
Enter student name: Kaeli
Enter test score: 77
Enter student name: Mel
Enter test score: 92
Enter student name: Juan
Enter test score: 95
Data written to file.
```

## Review: Stats – part 2 of 2

Modify the Stats application to allow the user to enter the names and grades of the students. The user should be prompted for the name of the file to create and for the number of student grades that will be entered. After the data has been entered and the written to a file, the file should be read and the lowest, highest, and average score displayed.

## Object Serialization

A file can also be used to store object data. Writing objects to a file is called *object serialization*. In this process, class information about an object is written out to a stream. If a class uses another class, this information is also written out, and so on. When information about an object is retrieved from a file, it is called *object deserialization*.

Object serialization and deserialization is performed with object output and input streams. The `FileOutputStream` and `ObjectOutputStream` classes, both from the `java.io` package, are used together to write objects to a file. The `FileInputStream` and `ObjectInputStream` classes, also from the `java.io` package, are used together to read objects from a file. Some of the methods from the classes for writing and reading objects include:

Class `FileOutputStream` (`java.io`)

Constructor/Method

`FileOutputStream(File fileName, boolean append)`

creates an output file stream for the `File` object. If `append` is true, then data written to the file will be added after existing data, otherwise the file will be overwritten or created if the file does not exist. This method throws a `FileNotFoundException` exception if the file cannot be opened or created.

`close()`

closes the output file stream. This method throws an `IOException` exception if the file cannot be closed.

In addition to methods for writing objects to the output stream, the ObjectOutputStream class also contains method for writing primitive data types.

**Class ObjectOutputStream (java.io)**  
**Constructor/Method**  
ObjectOutputStream(FileOutputStream stream)  
creates an object stream from `stream`.  
`writeObject(Object obj)`  
writes object information to the output stream. This method throws an IOException exception if there are problems with the class or if the stream cannot be written to.  
`writeInt(int num)`  
writes an `int` to the output stream. This method throws an IOException exception if the stream cannot be written to.  
`writeDouble(double num)`  
writes a `double` to the output stream. This method throws an IOException exception if the stream cannot be written to.  
`close()`  
closes the output stream. This method throws an IOException exception if the stream cannot be closed.

Objects are read from a FileInputStream stream object:

**Class FileInputStream (java.io)**  
**Constructor/Method**  
FileInputStream(File fileName)  
creates an input file stream for the File object. This method throws a FileNotFoundException exception if the file cannot be read.  
`close()`  
closes the input file stream. This method throws an IOException exception if the file cannot be closed.

The ObjectInputStream class contains method for reading both objects and primitive data types.

**Class ObjectInputStream (java.io)**  
**Constructor/Method**  
ObjectInputStream(FileInputStream stream)  
creates an object stream from `stream`. This constructor throws an IOException exception if the stream cannot be read.  
`readObject()`  
reads an object from the input stream. This method throws exceptions IOException and ClassNotFoundException if the the stream cannot be read or a class cannot be deserialized.  
`readInt()`  
reads an `int` from the input stream. This method throws an IOException exception if the file cannot be read.

`readDouble()` reads a double from the input stream. This method throws an IOException exception if the file cannot be read.

`close()` closes the input stream. This method throws an IOException exception if the file cannot be closed.

The ObjectWriteRead application demonstrates writing and reading objects from a file:

```
import java.io.*;

public class ObjectWriteRead {

 public static void main(String[] args) {
 File stuFile = new File("students.dat");

 try {
 /* write objects */
 FileOutputStream out = new FileOutputStream(stuFile);
 ObjectOutputStream writeStu = new ObjectOutputStream(out);
 writeStu.writeObject(new Student("Drew", 87));
 writeStu.writeObject(new Student("Tia", 92));
 writeStu.close();
 System.out.println("Data written to file.");

 /* read objects */
 FileInputStream in = new FileInputStream(stuFile);
 ObjectInputStream readStu = new ObjectInputStream(in);
 Student stu1 = (Student)readStu.readObject();
 Student stu2 = (Student)readStu.readObject();
 readStu.close();

 System.out.println(stu1);
 System.out.println (stu2);

 } catch (FileNotFoundException e) {
 System.out.println("File could not be found.");
 System.err.println("FileNotFoundException: " +
 + e.getMessage());
 } catch (IOException e) {
 System.out.println("Problem with input/output.");
 System.err.println("IOException: " + e.getMessage());
 } catch (ClassNotFoundException e) {
 System.out.println("Class could not be used to
 cast object.");
 System.err.println("ClassNotFoundException: " +
 + e.getMessage());
 }
 }
}
```

The ObjectWriteRead application writes two Student objects to the students.dat file. The Student class is shown on the next page:

```

import java.io.*;

public class Student implements Serializable {
 private String stuName;
 private double stuGrade;

 /**
 * constructor
 * pre: none
 * post: A Student object has been created.
 * Student data has been initialized with parameters.
 */
 public Student(String name, double grade) {
 stuName = name;
 stuGrade = grade;
 }

 /**
 * Creates a string representing the student object
 * pre: none
 * post: A string representing the student object
 * has been returned.
 */
 public String toString() {
 String stuString;

 stuString = stuName + " grade: " + stuGrade;
 return(stuString);
 }
}

```

### *Serializable interface*

If the objects of a class are to be written to a file, the class must implement the Serializable interface. This interface is part of the java.io package and contains no methods to implement. It simply allows information about an instance of the class to be written out.

Note that reading an object from a file requires casting. The readObject() method reads Object data from the file. It is up to the programmer to cast the object to the appropriate type.

The ObjectOutputStream application catches several exceptions. First, a FileNotFoundException occurs when there is a problem creating a File object. IOException is a more general exception and occurs for various input/output problems. If IOException were first in the catch clauses, the other more specific exceptions would not be caught and the user would not be able to read their descriptive error messages. Finally, the ClassNotFoundException occurs if the class for an object written to the file cannot be found.

## Review: Roster

Create a Roster application that prompts the user for the name of the file to store student names and then prompts the user for the number of students in a class. The application should then prompt the user for the first and last name of each student and write this data to a file. After all the data is written to a file, the application displays the class roster with one name after the other in a list. Create a StuName class that has member variables `firstName` and `lastName` and a `toString()` member method.

## Chapter 12 Case Study

In this case study, a LocalBank2 application will be created. LocalBank2 is the Chapter 10 case study modified to read and write account information from a file.

### LocalBank2 Specification

The LocalBank2 application has the same specification as LocalBank. It allows accounts to be opened, modified, and closed. Each account has a unique account number, which is required for all transactions. Transactions include deposits and withdrawals. An account balance can also be checked.

The LocalBank2 interface will not change from LocalBank. It will provide a menu of options:

```
Deposit\Withdrawal\Check balance
Add an account\Remove an account
Quit

Enter choice: a
First name: Adriana
Last name: Lee
Beginning balance: 100
Account created. Account ID is: ALee

Deposit\Withdrawal\Check balance
Add an account\Remove an account
Quit

Enter choice: D
Enter account ID: ALee
Deposit amount: 22
ALee
Adriana Lee
Current balance is $122

Deposit\Withdrawal\Check balance
Add an account\Remove an account
Quit

Enter choice:
```

The LocalBank2 algorithm will not change from the LocalBank application algorithm.

## LocalBank2 Code Design

The LocalBank2 application will be modeled with a Bank object, Account objects, and Customer objects, just as LocalBank. However, the Bank object will store and retrieve accounts from a file. To do this, the Bank constructor should create a file stream for the File object specified when the Bank object is instantiated. The constructor should also load accounts from the file stream into an ArrayList. An updateAccounts() method will need to be added to the Bank class so that any account changes can be written back to the file.

Because account objects will be read from and written to a file, the Account class and any classes it uses must implement the Serializable interface. This includes the Customer class.

The LocalBank2 client code must be modified to create a File object that stores the account information. Before ending the LocalBank application, the updateAccounts() method is called to write account information back to the file. The pseudocode for the LocalBank2 client code follows:

```
File accountsFile = new File("LBAccounts.dat");
Bank easySave = new Bank(accountsFile);

do {
 prompt user for transaction type

 if (add account) {
 easySave.addAccount();
 } else if (not Quit) {
 prompt user for account ID;
 if (deposit) {
 prompt user for deposit amount
 easySave.transaction(make deposit, acctID, amt);
 } else if (withdrawal) {
 prompt user for withdrawal amount
 easySave.transaction(make withdrawal, acctID, amt);
 } else if (check balance) {
 easySave.checkBalance(acctID);
 } else if (remove account) {
 easySave.deleteAccount(acctID);
 }
 }
} while (not quit);
easySave.updateAccounts(accountsFile);
```

## LocalBank Implementation

The LocaBank2 application is shown below:

```
/**
 * LocalBank2 client code.
 */

import java.io.*;
import java.util.Scanner;

public class LocalBank {

 public static void main(String[] args) {
 File accountsFile = new File("LBAccounts.dat");
 Bank easySave = new Bank(accountsFile);
```

```

Scanner input = new Scanner(System.in);
String action, acctID;
Double amt;

/* display menu of choices */
do {
 System.out.println("\nDeposit\\Withdrawal\\Check balance");
 System.out.println("Add an account\\Remove an account");
 System.out.println("Quit\n");
 System.out.print("Enter choice: ");
 action = input.next();

 if (action.equalsIgnoreCase("A")) {
 easySave.addAccount();
 } else if (!action.equalsIgnoreCase("Q")) {
 System.out.print("Enter account ID: ");
 acctID = input.next();
 if (action.equalsIgnoreCase("D")) {
 System.out.print("Enter deposit amount: ");
 amt = input.nextDouble();
 easySave.transaction(1, acctID, amt);
 } else if (action.equalsIgnoreCase("W")) {
 System.out.print("Enter withdrawal amount: ");
 amt = input.nextDouble();
 easySave.transaction(2, acctID, amt);
 } else if (action.equalsIgnoreCase("C")) {
 easySave.checkBalance(acctID);
 } else if (action.equalsIgnoreCase("R")) {
 easySave.deleteAccount(acctID);
 }
 }
} while (!action.equalsIgnoreCase("Q"));

easySave.updateAccounts(accountsFile); //write accounts to file
}
}

```

The Bank class is shown below. The accounts are expected to be loaded from a file. Additionally, the number of accounts is also kept in the file. This number is the first data item in the file. It is read first and then used to determine how many accounts to read from the file. Throughout the class, the number of accounts is updated when a new account is added and when an account is deleted. When updateAccounts() is called, the number of accounts is written to the file first, followed by the accounts:

```

/**
 * Bank class.
 */

import java.util.ArrayList;
import java.io.*;
import java.util.Scanner;

public class Bank {
 private ArrayList accounts;
 private int numAccts;

```

```

 /**
 * constructor
 * pre: none
 * post: accounts have been loaded from acctFile.
 */
 public Bank(File acctsFile) {
 accounts = new ArrayList();
 Account acct;

 /* Create a new file for accounts if one does not exist */
 if (!acctsFile.exists()) {
 try {
 acctsFile.createNewFile();
 System.out.println("There are no existing accounts.");
 } catch (IOException e) {
 System.out.println("File could not be created.");
 System.err.println("IOException: " + e.getMessage());
 }
 numAccts = 0;
 } else { /* load existing accounts */
 try {
 FileInputStream in = new FileInputStream(acctsFile);
 ObjectInputStream readAccts = new ObjectInputStream(in);
 numAccts = (int)readAccts.readInt();
 if (numAccts == 0) {
 System.out.println("There are no existing accounts.");
 } else {
 for (int i = 0; i < numAccts; i++) {
 acct = (Account)readAccts.readObject();
 accounts.add(acct);
 }
 }
 readAccts.close();
 } catch (FileNotFoundException e) {
 System.out.println("File could not be found.");
 System.err.println("FileNotFoundException: " + e.getMessage());
 } catch (IOException e) {
 System.out.println("Problem with input/output.");
 System.err.println("IOException: " + e.getMessage());
 } catch (ClassNotFoundException e) {
 System.out.println("Class could not be used to cast object.");
 System.err.println("ClassNotFoundException: " + e.getMessage());
 }
 }
 }

 /**
 * Adds a new account to the bank accounts.
 * pre: none
 * post: An account has been added to the bank's accounts.
 */
 public void addAccount() {
 Account newAcct;
 double bal;
 String fName, lName;
 Scanner input = new Scanner(System.in);

 System.out.print("First name: ");
 fName = input.nextLine();
 System.out.print("Last name: ");
 lName = input.nextLine();
 System.out.print("Beginning balance: ");
 bal = input.nextDouble();
 }
}

```

```

 newAcct = new Account(bal, fName, lName); //create account object
 accounts.add(newAcct); //add account to bank accounts
 numAccts += 1; //increment number of accounts

 System.out.println("Account created. Account ID is: " + newAcct.getID());
 }

 /**
 * Deletes an existing account.
 * pre: none
 * post: An existing account has been deleted.
 */
 public void deleteAccount(String acctID) {
 int acctIndex;
 Account acctToMatch;

 acctToMatch = new Account(acctID);
 acctIndex = accounts.indexOf(acctToMatch);
 if (acctIndex > -1) {
 accounts.remove(acctIndex);
 System.out.println("Account removed.");
 numAccts -= 1;
 } else {
 System.out.println("Account does not exist.");
 }
 }
}

```

The Account class need only be modified to implement the Serializable class:

```

/**
 * Account class.
 */

import java.io.*;
import java.text.NumberFormat;

public class Account implements Serializable {
 ...rest of Account class (refer to Chapter 10 case study)
}

```

The Customer class need only be modified to implement the Serializable class:

```

/**
 * Customer class.
 */

import java.io.*;

public class Customer implements Serializable {
 ...rest of Customer class (refer to Chapter 10 case study)
}

```

Running the LocalBank2 application displays the same output as the LocalBank application:

```
Deposit\Withdrawal\Check balance
Add an account\Remove an account
Quit

Enter choice: a
First name: Sam
Last name: Iam
Beginning balance: 100
Account created. Account ID is: $Iam

Deposit\Withdrawal\Check balance
Add an account\Remove an account
Quit

Enter choice: D
Enter account ID: $Iam
Enter deposit amount: 22
$Iam
Sam Iam
Current balance is $122

Deposit\Withdrawal\Check balance
Add an account\Remove an account
Quit

Enter choice:
```

### LocalBank2 Testing and Debugging

The LocalBank2 application should be tested to be sure that it works appropriately when no file exists, when a file with no accounts exists, and when a file with accounts exists.

## Review: LocalBank2

Modify the Bank class to keep track of accounts with low balances. A low balance is an account with less than \$20.00. The number of low balance accounts should be stored after the number of accounts, but before the account objects in the account file. Have the number of low balance accounts displayed when a Bank object is created and again when the updateAccounts() method is called.

## Chapter Summary

This chapter discussed files and exception handling. A file is a data stored on a persistent medium such as a hard disk or CD. In Java, a File object is associated with a file name. A File object can be used to create or delete a file.

An exception is an error affecting program execution. An exception handler is a block of code that performs an action when an exception occurs. This chapter introduced the `try-catch-finally` statement for writing exception handlers.

A file must be associated with a stream in order to read and write to the file. A file stream processes characters and is used to perform sequential file access. The FileReader, BufferedReader, FileWriter, and BufferedWriter classes are used to read and write to a file.

An application written to process numeric data from a file must convert the file data from strings to numerics. The Double and Integer classes contain methods for converting numeric characters in a string to an `int` or a `double`.

Objects can be written to a file in a process called object serialization. Reading objects from a file is called object deserialization. Serialization and deserialization are performed with an object stream. The FileOutputStream, ObjectOutputStream, FileInputStream, and ObjectInputStream classes are used to write and read objects to a file. The ObjectOutputStream and ObjectInputStream classes can also be used to write and read primitive data to a file.

## Vocabulary

**ClassNotFoundException** An exception thrown if a stream cannot be read or a class cannot be serialized.

**End of file** A -1 in the file stream.

**err stream** The stream used for displaying error messages to the user.

**Exception** An error affecting program execution.

**Exception handler** A block of code that performs an action when an exception occurs.

**File** A collection of related data stored on a persistent medium.

**FileNotFoundException** An exception thrown when a file does not exist.

**File position** The point at which reading or writing in the stream last occurred.

**Handle** Take care of.

**Input file stream** A file stream for reading a file.

**IOException** An exception thrown when a file cannot be created, or when there is a general input/output problem.

**Line terminator** A carriage return followed by a line feed in the file stream.

**Object deserialization** The process used to read objects from a file.

**Object serialization** The process used to write objects to a file.

**Output file stream** A file stream for writing to a file.

**Persistent** Lasting.

**Sequential file access** Reading and writing one character after another.

**Stream** The construct used for processing characters.

**Throw** Generate.

## Java

**BufferedReader** A java.io class used for creating a buffered file stream for reading a file.

**BufferedWriter** A java.io class used for creating a buffered file stream for writing to a file.

**Double** A java.lang class for converting numeric text in a string to a double.

**File** The java.io class used for creating an object that refers to a file.

**FileInputStream** A java.io class used for creating an object input stream.

**FileOutputStream** A java.io class used for creating an object output stream.

**FileReader** The java.io class used for creating a file stream for reading a file.

**FileWriter** The java.io class used for creating a file stream for writing to a file.

**Integer** A java.lang class for converting numeric text in a string to an int.

**try-catch-finally** Statement used to write an exception handler.

**ObjectInputStream** A java.io class used for creating an object for reading objects from a file.

**ObjectOutputStream** A java.io class used for creating an object for writing objects to a file.

## Critical Thinking

1. Can data in memory be called a file? Explain.
2. Write the `import` statement required to access the File Class in an application.
3. Identify the error in the following statement:  
`File textFile = new File("c:\\inventory.txt");`
4.
  - a) Which statement is used to write an exception handler?
  - b) Write an exception handler to handle an `IOException` if a specified file name cannot be used to create a file. The exception handler should display appropriate messages to the user.
5.
  - a) What is the name of the stream for displaying error messages.
  - b) Where are these messages displayed?
6.
  - a) What does the file stream keep track of?
  - b) What characters together make up a line terminator?
7. What two classes are used together to write data to a file?
8. Write a statement to convert account balances that have been read from a text file to a `double` value and add them to `totalBalance`.
9. Explain the difference between object serialization and object deserialization.
10. What interface must be implemented if objects of a class are to be written to a file?
11. Describe two situations where an `IOException` exception could be thrown, and write an example exception handler for each situation to output an appropriate message if the exception occurs.

### True/False

12. Determine if each of the following are true or false. If false, explain why.
  - a) An exception always results in program termination.
  - b) Sequential file access reads and writes data one character after another or one line after another.

## Exercises

### Exercise 1

### WordCount

Create a WordCount application that displays the number of words and the average word length in a text file named source.txt. Consider a word to be any sequence of letters terminated by nonletters. For example, forty-nine is two words.

### Exercise 2

### WordStats

- Create a WordStats application that lists all the unique words in a file and how many times they occurred. WordStats should ignore capitalization. The application should provide a listing similar to:

| WORD | OCCURENCES |
|------|------------|
| the  | 57         |
| and  | 12         |
| zoo  | 3          |

- Modify the WordStats application to list the words in alphabetical order. This can be done by either using the sorting algorithm presented in Chapter 10, Exercise 11 or by keeping the words in order as they are read.

### Exercise 3

### TestProcessor

Test results for a multiple choice test can be stored in a text file as follows:

- Line 1: The correct answers, one character per answer
- Line 2: Name of the first student (length <= 30 chars)
- Line 3: Answers for the student in line 2
- The remaining lines: student names and answers on separate lines

For example:

```
BAGED
Smithgall
BADD
DeSalvo
CAEED
Darji
BAGED
```

Create a TestProcessor application that processes the test results file for any number of students. The application should provide statistics similar to:

|           |      |
|-----------|------|
| Smithgall | 80%  |
| DeSalvo   | 60%  |
| Darji     | 100% |

## Exercise 4

## MadLib

A Mad-Lib story is a story where nouns and verbs in a paragraph are randomly replaced with other nouns and verbs, usually with humorous results. Create a MadLib application that displays a Mad-Lib story. The application will require three files:

- story.txt which contains a story with # signs as noun placeholders, and % signs as verb placeholders. For example:

```
Bugsy Kludge is a # with our company.
His job is to % all of the #s.
```

- verbs.txt which contains verbs, one per line. For example:

```
run
display
eat
```

- nouns.txt which contains nouns, one per line. For example:

```
banana
soprano
elephant
vegetable
```

Application output should display the story with appropriate replacements made. A possible output would produce a MadLib similar to:

```
Bugsy Kludge is a vegetable with our company.
His job is to display all of the elephants.
```

## Exercise 5

## MergeFiles

The idea of merging two or more files is an important one in programming. One approach is to merge the ordered data of two files into a third file, keeping the data in order.

Create a MergeFiles application that merges the integers ordered from low to high in two files into a third file, keeping the order from low to high. For example, two files of integers could contain:

```
File 1: 12 23 34 45 56 67 69 123 133
File 2: 4 5 10 20 35 44 100 130 150 160 180
```

The application should not use an array to temporarily store the numbers, but should merge the two files by taking one element at a time from each. After MergeFiles has been run, the third file should contain:

```
4 5 10 12 20 23 34 35 44 45 56 67 69 100 123 130 133 150 160 180
```

## Exercise 6

## MergeLarge

The algorithm used implemented in Exercise 5 is sometimes used as part of a sorting algorithm with data that is too large to be stored in memory at once. For example, to sort a large file large.dat that is twice as large as will fit in memory, half can be read into an array, the array sorted, and then written to a file numbers1.dat. Next, the second half of large.dat can be read into the array, sorted, and then written to numbers2.dat. Finally, the two files can be merged in order back into large.dat. Create a MergeLarge application that implements this algorithm. Test the application with a file that contains 30 integers sorted from low to high.

## Exercise 7

## HTMLViewer

The early success of the Web is largely due to the simplicity of HTML (HyperText Markup Language), for designing a Web page. HTML documents are text documents containing content and tags that describe the format of the content. An HTML document could look similar to:

```
JUNE BUGS<p>June bugs RAM in megabytes of fleshy fruit,
downsize fine fat
figs
chip away at melon bits.
They monitor windows for open screens,
seeking
felicity in electricity.
Built-in memory warns of websites
hiding spiders
with sly designs.
Scrolling the scene of leaves and trees,
they network the
neighborhood in flashy green jackets,
each bug a browser, scanner, looter-

not even knowing the word "computer."<p>by Avis Harley<p><hr>
```

Tags are enclosed in angle brackets, < >. The tag <br> means to start a new line. The tag <p> means to start a new paragraph (a blank line). The tag <hr> means to draw a horizontal rule. When these tags are interpreted, the HTML document above is displayed as:

JUNE BUGS

```
June bugs RAM in megabytes of fleshy fruit,
downsize fine fat figs
chip away at melon bits.
They monitor windows for open screens,
seeking felicity in electricity.
Built-in memory warns of websites
hiding spiders with sly designs.
Scrolling the scene of leaves and trees,
they network the neighborhood in flashy green jackets,
each bug a browser, scanner, looter-
not even knowing the word "computer."
```

by Avis Harley

- 
- a) HTML documents are interpreted by browser software. Create an HTMLViewer application that interprets an HTML file to display the Web content as intended, similar to the way a browser decides how to display an HTML document.
  - b) Modify the HTMLViewer application to allow the user to specify the display line width. For example, a width of 35 should display the HTML document as:

JUNE BUGS

```
June bugs RAM in megabytes of
fleshy fruit,
downsize fine fat figs
chip away at melon bits.
They monitor windows for open
screens,
seeking felicity in electricity.
Built-in memory warns of websites
hiding spiders with sly designs.
Scrolling the scene of leaves and
trees,
they network the neighborhood in
flashy green jackets,
each bug a browser, scanner,
looter-
not even knowing the word
"computer."
```

by Avis Harley

## Exercise 8



## CarRecall

Modify the CarRecall application created in Chapter 6, Exercise 4 to load the defective car model numbers from a file.

## Exercise 9



## WordGuess

Modify the WordGuess case study from Chapter 6 to use a word from a file as the secret word. The file should contain a list of words, with one word per line. The WordGuess application should determine which word to use, by generating a random number that corresponds to one of the words in the file.

## Exercise 10

## FindAndReplace

Create a FindAndReplace application that prompts the user for a file name, a search word or phrase, and a replacement word or phrase. After entering the replacement word or phrase, FindAndReplace finds all occurrences of the search word or phrase in a file and replaces them with the specified replacement word or phrase.

## Exercise 11

## ApplicationDoc

Create an ApplicationDoc application that prompts the user for the file name of a Java source code file (the file name extension should be `.java`) and then copies all the documentation comments (`/** */`) to a separate file.

## Exercise 12



## MySavings

Modify the MySavings application from Chapter 8, Exercise 1 to store and load the PiggyBank object from a file.

## Exercise 13



## Adder

Modify the Adder application from Chapter 8, Exercise 8 to keep track of player scores in a file. The application should prompt the player for his or her name and then create a file based on the player name. For example, if the player's name is Jo, then a file named `JoScores.txt` should be created. The application should write the player's score to their file at the end of the game and then display the player's previous scores.

## Exercise 14



## CountVowels

Modify the CountVowels application created in Chapter 6, Exercise 20 to count the number of vowels in a text file. The application should prompt the user for the file name.

**Exercise 15** **Coder**

Modify the Coder application created in Chapter 10, Exercise 10 to encode the text in one file and write it to a new file.

**Exercise 16** **CourseGrades**

Modify the CourseGrades application created in Chapter 10, Exercise 12 to write the GradeBook object to a file.

**Exercise 17** **Life**

Modify the Life application created in Chapter 10, Exercise 14 to retrieve the initial life grid from a file.

**Exercise 18** **Inventory**

Modify the Inventory application created in Chapter 10, Exercise 16 to write the inventory items to a file.

# Chapter 13

## Recursion and Advanced Algorithms

**A**lgorithms for searching and sorting data will be covered in this chapter. Recursion will be used in the implementation of some of these algorithms.

### Selection Sort

Sorting is the process of putting items in a designated order, either from low to high or high to low. The *selection sort* algorithm starts by finding the lowest item in a list and swapping it with the first. Next, the lowest item among items 2 through the last is found and swapped with item 2, and then the lowest item among items 3 through the last is swapped with item 3. This process is continued until the last item is reached, at which point all the items are sorted.

The selection sort algorithm compares an element to the items in the array after the element. This algorithm can be implemented with nested `for` loops. The outer loop controls which element to compare and the inner `for` loop iterates through the array after the element (the subarray). The selection sort pseudocode for sorting an array of items from low to high appears like:

```
for (arrayIndex = 0 to numItems-1)
 for (subarrayIndex = arrayIndex to numItems-1)
 if (items[subarrayIndex] < items[arrayIndex]) {
 swap items[arrayIndex] and items[subarrayIndex]
 }
 }
```

The `Sorts` class on the next page implements a `selectionSort()` method:

```

public class Sorts {

 /**
 * Sorts an array of data from low to high
 * pre: none
 * post: items has been sorted from low to high
 */
 public static void selectionSort(int[] items) {

 for (int index=0; index<items.length; index++) {
 for (int subIndex=index; subIndex<items.length; subIndex++) {
 if (items[subIndex] < items[index]) {
 int temp = items[index];
 items[index] = items[subIndex];
 items[subIndex] = temp;
 }
 }
 }
 }
}

```

The TestSorts application generates an array of integers and then calls selectionSort() to sort the array elements:

```

import java.util.Scanner;
import java.util.Random;

public class TestSorts {

 public static void displayArray(int[] array) {
 for (int i = 0; i < array.length; i++) {
 System.out.print(array[i] + " ");
 }
 System.out.println("\n");
 }

 public static void main(String[] args) {
 Scanner input = new Scanner(System.in);
 int numItems;
 int[] test;
 Random rand = new Random();

 System.out.print("Enter number of elements: ");
 numItems = input.nextInt();

 /* populate array with random integers */
 test = new int[numItems];
 for (int i = 0; i < test.length; i++) {
 test[i] = rand.nextInt(100);
 }
 System.out.println("Unsorted:");
 displayArray(test);

 Sorts.selectionSort(test);

 System.out.println("Sorted:");
 displayArray(test);
 }
}

```

The TestSorts application produces output similar to:

```
Enter number of elements: 10
Unsorted:
91 36 4 65 45 67 87 93 24 48

Sorted:
4 24 36 45 48 65 67 87 91 93
```

## Sorting Objects

*equals(), compareTo()*

Relational operators, such as `>` and `<`, cannot be used to compare objects. Objects use methods of their class to determine if one object is greater than, less than, or equal to another. The `equals()` method in a class is used to determine equality. For determining order, the `compareTo()` method is used.

*Comparable interface*

*polymorphism*

Objects that are to be sorted must have a class that implements the Comparable interface. The String, Double, and Integer classes implement the Comparable interface. The Circle class in Chapter 9 also implements the Comparable interface.

An interface cannot be used to instantiate a class. However, an interface can be used as a data type. An interface data type can reference any class that implements it. This polymorphic behavior makes it possible to implement a generic sort that works with any list of objects that implement the Comparable interface.

The Sorts class has been modified to include an overloaded SelectionSort() method, which has a Comparable array parameter:

```
/*
 * Sorts an array of objects from low to high
 * pre: none
 * post: Objects have been sorted from low to high
 */
public static void selectionSort(Comparable[] items) {

 for (int index = 0; index < items.length; index++) {
 for (int subIndex=index; subIndex<items.length; subIndex++) {
 if (items[subIndex].compareTo(items[index]) < 0) {
 Comparable temp = items[index];
 items[index] = items[subIndex];
 items[subIndex] = temp;
 }
 }
 }
}
```

The TestSorts application, on the next page, has been modified to sort an array of Circle objects:

```

import java.util.Scanner;
import java.util.Random;

public class TestSorts {

 public static void displayArray(Circle[] array) {
 for (int i = 0; i < array.length; i++) {
 System.out.println(array[i] + " ");
 }
 System.out.println("\n");
 }

 public static void main(String[] args) {
 Scanner input = new Scanner(System.in);
 int numObjects;
 Circle[] test;
 Random rand = new Random();

 System.out.print("Enter number of objects: ");
 numObjects = input.nextInt();
 input.close();

 /* populate array with Circle objects of varying radii */
 test = new Circle[numObjects];
 for (int i = 0; i < test.length; i++) {
 test[i] = new Circle(rand.nextInt(10));
 }
 System.out.println("Unsorted:");
 displayArray(test);

 Sorts.selectionSort(test);

 System.out.println("Sorted:");
 displayArray(test);
 }
}

```

The TestSorts application produces output similar to:

```

Enter number of objects: 5
Unsorted:
Circle has radius 5.0
Circle has radius 6.0
Circle has radius 5.0
Circle has radius 3.0
Circle has radius 8.0

Sorted:
Circle has radius 3.0
Circle has radius 5.0
Circle has radius 5.0
Circle has radius 6.0
Circle has radius 8.0

```

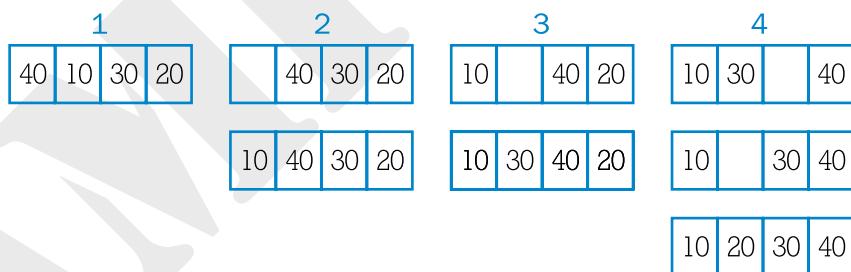
## Review: ArrayListSort

Create an `ArrayListSort` application that implements a selection sort on an `ArrayList` object. Test the sort with an `ArrayList` containing `Double` objects.

### Insertion Sort

More efficient than the selection sort algorithm is the insertion sort algorithm. An *insertion sort* starts by sorting the first two items in a list. This sort is performed by shifting the first item into the second spot if the second item belongs in the first spot. Next, the third item is properly inserted within the first three items by again shifting items into their appropriate position to make room for the moved item. This process is repeated for the remaining elements.

The insertion sort is illustrated below with an array containing four elements. Step 1 shows the original list, which contains items 40, 10, 30, and 20. Step 2 shows that 40 is shifted to make room for the second item, 10. Next, 30 compared to the value in the previous position (40), 40 is shifted into position 3, 30 is then compared to the value in the previous position (10), and then 30 is placed at position 2. This process repeats for the remaining items.



Based on the algorithm, the insertion sort pseudocode for an array of integers is:

```
for (index = 1 To array.length - 1) {
 temp = array[index]
 previousIndex = index - 1
 while (array[previousIndex] > temp && previousIndex > 0) {
 shift array[previousIndex] up one element
 previousIndex = previousIndex - 1
 }
 if (array[previousIndex] > temp) {
 swap the two elements
 } else {
 insert element at appropriate location
 }
}
```

The Sorts class has been modified to include an insertionSort() method:

```
/*
 * Sorts an array of integer from low to high
 * pre: none
 * post: Integers have been sorted from low to high
 */
public static void insertionSort(int[] items) {
 int temp, previousIndex;

 for (int index = 1; index < items.length; index++) {
 temp = items[index];
 previousIndex = index - 1;
 while ((items[previousIndex] > temp) && (previousIndex > 0)) {
 items[previousIndex + 1] = items[previousIndex];
 previousIndex -= 1; //decrease index to compare current
 } //item with next previous item
 if (items[previousIndex] > temp) {
 /* shift item in first element up into next element */
 items[previousIndex + 1] = items[previousIndex];
 /* place current item at index 0 (first element) */
 items[previousIndex] = temp;
 } else {
 /* place current item at index ahead of previous item */
 items[previousIndex + 1] = temp;
 }
 }
}
```

The TestSorts application has been modified to use the insertionSort() method to sort an array of integers:

```
import java.util.Scanner;
import java.util.Random;

public class TestSorts {

 public static void displayArray(int[] array) {
 for (int i = 0; i < array.length; i++) {
 System.out.print(array[i] + " ");
 }
 System.out.println("\n");
 }

 public static void main(String[] args) {
 Scanner input = new Scanner(System.in);
 int numItems;
 int[] test;
 Random rand = new Random();

 System.out.print("Enter number of elements: ");
 numItems = input.nextInt();

 /* populate array with random integers */
 test = new int[numItems];
 for (int i = 0; i < test.length; i++) {
 test[i] = rand.nextInt(100);
 }
 System.out.println("Unsorted:");
 displayArray(test);

 Sorts.insertionSort(test);
 }
}
```

```

 System.out.println("Sorted:");
 displayArray(test);
 }
}

```

The TestSorts application produces output similar to:

```

Enter number of elements: 10
Unsorted:
65 52 75 10 44 86 37 14 13 39

Sorted:
10 13 14 37 39 44 52 65 75 86

```

## Review: ObjectsInsertionSort

Create an ObjectsInsertionSort application that implements an insertion sort on an array of objects. Test the sort on an array of String objects.

## Recursion

A method can call itself. This process is called *recursion* and the calls are referred to as *recursive calls*. The RecursiveDemo application contains a method that calls itself:

```

public class RecursiveDemo {

 public static void showRecursion(int num) {
 System.out.println("Entering method. num = " + num);
 if (num > 1) {
 showRecursion(num - 1);
 }
 System.out.println("Leaving method. num = " + num);
 }

 public static void main(String[] args) {
 showRecursion(2);
 }
}

```

The call `showRecursion(2)` from the `main()` method is the initial call. In the `showRecursion()` method, a call is made to itself passing `num - 1`. When `showRecursion` is called with `num` equal to 1, the `if` is skipped and the remaining statement in the method is executed. At this point the stack of calls made before `num` was 1 are executed in the reverse order they were made, with each call executing the statement in the method after the recursive call (after the `if`).

The RecursiveDemo produces the output shown on the next page:

```

Entering method. num = 2
Entering method. num = 1
Leaving method. num = 1
Leaving method. num = 2

```

Recursion is a programming technique that can be used whenever a problem can be solved by solving one or more smaller versions of the same problem and combining the results. The recursive calls solve the smaller problems.

One problem that has a recursive solution is raising a number to a power. For example,  $2^4$  can be thought of as:

$$\begin{aligned}
 2^4 &= 2 * 2^3 \text{ which can be thought of as} \\
 2^3 &= 2 * 2^2 \text{ which can be thought of as} \\
 2^2 &= 2 * 2^1 \text{ which can be thought of as} \\
 2^1 &= 2 * 2^0 \text{ which can be thought of as} \\
 &\quad 1
 \end{aligned}$$

In each case, the power problem is reduced to a smaller power problem. A more general solution is:

$$x^n = x * x^{n-1}$$

### **infinite recursion**

### **base case**

However, carefully analyzing this solution shows that there is no stopping point. For example,  $2^3$  would be  $2 * 2^2$ , which would return  $2 * 2^1$ , which returns  $2 * 2^0$ , which returns  $2 * 2^{-1}$ , and so on. This solution would cause *infinite recursion*. To prevent this, a recursive solution must have a *base case* that requires no recursion. For this solution, when the power is 0, 1 should be returned.

The `intPower()` method in the Power application implements a recursive solution for calculating an `int` raised to an `int` power to return an `int` (as opposed to `Math.pow()`, which returns a `double`):

```

public class Power {

 /**
 * Returns num to the power power.
 * pre: num and power are not 0.
 * post: num to the power power has been returned.
 */
 public static int intPower(int num, int power) {
 int result;
 if (power == 0) {
 result = 1;
 } else {
 result = num * intPower(num, power-1);
 }
 return(result);
 }

 public static void main(String[] args) {
 int x = intPower(2, 5);
 System.out.println(x);
 }
}

```

The Power application produces the output:

## Review: RecursiveFactorial

Create a RecursiveFactorial application that returns the factorial of an integer. The factorial of a number is the product of all positive integers from 1 to the number. For example,  $5! = 5*4*3*2*1$ . Computing  $5!$  could be thought of as  $5*4!$  or more generally,  $n*(n-1)!$ . By definition,  $0!$  is equal to 1. Compare your recursive solution to the nonrecursive solution created in the Factorial Review completed in Chapter 6.

## Mergesort

**TIP** Measuring an algorithm's efficiency is discussed later in this chapter.

The selection sort is simple, but inefficient, especially for large arrays. Imagine using the selection sort process by hand for a pile of 1000 index cards. Searching through the cards for the lowest item would take a long time, but more importantly, after each search the remaining cards must be searched again! Each card ends up being examined about 500 times.

The *mergesort* algorithm takes a “divide-and-conquer” approach to sorting. Imagine the 1000 cards being divided into two piles of 500. Each pile could then be sorted (a simpler problem) and the two sorted piles could be combined (merged) into a single ordered pile. To further simplify the sorting, each subpile could be divided and sorted, and so on. This algorithm is best implemented recursively.

The mergesort pseudocode is:

```
if there are items remaining {
 mergesort the left half of the items
 mergesort the right half of the items
 merge the two halves into a completely sorted list
}
```

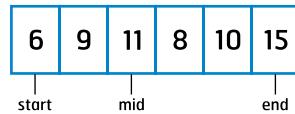
The mergesort subtasks are recursive calls to `mergeSort()` and a call to `merge()`. The `mergesort()` method will need arguments indicating which portion of the array is to be sorted. Similarly, `merge()` implements the merging of two halves and needs arguments indicating which portion of the array is to be merged.

The `mergesort()` method is defined as:

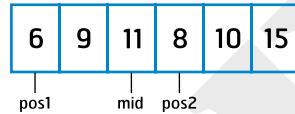
```
/**
 * Sorts items[start..end]
 * pre: start > 0, end > 0
 * post: items[start..end] is sorted low to high
 */
public static void mergesort(int[] items, int start, int end) {
 if (start < end) {
 int mid = (start + end) / 2;
 mergesort(items, start, mid);
 mergesort(items, mid + 1, end);
 merge(items, start, mid, end);
 }
}
```

The stopping condition for the recursive function is determined by comparing `start` and `end`. The middle of the array is calculated using integer division, which automatically truncates the decimal portion of the quotient.

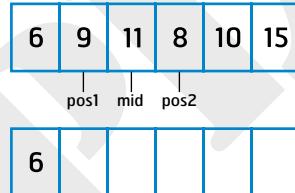
The merge() method uses a temporary array to store items moved from two sorted portions of the items array. The elements are moved so that the temporary array is sorted. To illustrate the merge() algorithm, suppose at entry to merge() the array looks like:



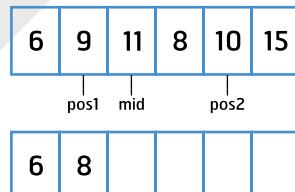
The array is sorted from `start` to `mid` and from `mid+1` to `end`. The merge() method starts by examining the first element of each sorted portion, `start` and `mid+1`, as indicated by `pos1` and `pos2`:



Since `items[pos1] < items[pos2]`, the element `items[pos1]` is moved to the new array, and `pos1` is incremented:



In this case, `items[pos1] > items[pos2]`, so the element `items[pos2]` is moved to the new array and `pos2` incremented:



This process is repeated until all items have been moved. Since it is likely that one array portion will be exhausted before the other, merge() tests for this case and just moves items from the remaining list. Finally, merge() copies the merged items in the temporary array to the original array.

The Sorts class has been modified to include a mergesort() method. Note that the merge() method is `private` because it is a helper method:

```

/**
 * Merges two sorted portion of items array
 * pre: items[start..mid] is sorted. items[mid+1..end] sorted.
 * start <= mid <= end
 * post: items[start..end] is sorted.
 */
private static void merge(int[] items, int start,
 int mid, int end) {
 int[] temp = new int[items.length];
 int pos1 = start;
 int pos2 = mid + 1;
 int spot = start;

 while (!(pos1 > mid && pos2 > end)) {
 if ((pos1 > mid) ||
 ((pos2 <= end) && (items[pos2] < items[pos1]))) {
 temp[spot] = items[pos2];
 pos2 += 1;
 } else {
 temp[spot] = items[pos1];
 pos1 += 1;
 }
 spot += 1;
 }
 /* copy values from temp back to items */
 for (int i = start; i <= end; i++) {
 items[i] = temp[i];
 }
}

/**
 * Sorts items[start..end]
 * pre: start > 0, end > 0
 * post: items[start..end] is sorted low to high
 */
public static void mergesort(int[] items, int start, int end) {
 if (start < end) {
 int mid = (start + end) / 2;
 mergesort(items, start, mid);
 mergesort(items, mid + 1, end);
 merge(items, start, mid, end);
 }
}

```

The `if` in the `merge()` method says that if the `pos1` (left) subarray is exhausted, or if the `pos2` (right) subarray is not exhausted and the `pos2` element is less than the `pos1` element, then move an item from the `pos2` subarray to the `temp` array, otherwise move an item from the `pos1` subarray. This process continues until both subarrays are exhausted.

The TestSorts application has been modified to use the mergesort() method to sort an array of integers:

```
import java.util.Scanner;
import java.util.Random;

public class TestSorts {

 public static void displayArray(int[] array) {
 for (int i = 0; i < array.length; i++) {
 System.out.print(array[i] + " ");
 }
 System.out.println("\n");
 }

 public static void main(String[] args) {
 Scanner input = new Scanner(System.in);
 int numItems;
 int[] test;
 Random rand = new Random();

 System.out.print("Enter number of elements: ");
 numItems = input.nextInt();

 /* populate array with random integers */
 test = new int[numItems];
 for (int i = 0; i < test.length; i++) {
 test[i] = rand.nextInt(100);
 }
 System.out.println("Unsorted:");
 displayArray(test);

 Sorts.mergesort(test, 0, test.length - 1);

 System.out.println("Sorted:");
 displayArray(test);
 }
}
```

The TestSorts application produces output similar to:

```
Enter number of elements: 10
Unsorted:
99 55 94 59 75 26 71 16 91 3

Sorted:
3 16 26 55 59 71 75 91 94 99
```

## Review: ObjectsMergesort

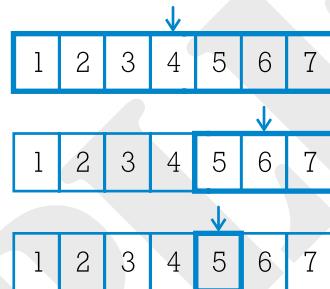
Create an ObjectsMergesort application that implements a mergesort on an array of objects. Test the sort on an array of String objects.

## Binary Search

**TIP** The linear search algorithm was introduced in Chapter 10. A linear search, also called a sequential search, is much less efficient than a binary search. However, a linear search does not require a sorted list.

Arrays are sorted in order to perform a more efficient search. A binary search is used with a sorted list of items to quickly find the location of a value. Like the mergesort algorithm, the binary search algorithm also takes a divide-and-conquer approach. It works by examining the middle item of an array sorted from low to high, and determining if this is the item sought, or if the item sought is above or below this middle item. If the item sought is below the middle item, then a binary search is applied to the lower half of the array; if above the middle item, a binary search is applied to the upper half of the array, and so on.

For example, a binary search for the value 5 in a list of items 1, 2, 3, 4, 5, 6, and 7 could be visualized as:



The binary search algorithm is very efficient. For example, an array of 100 elements checks no more than 8 elements in a search, and in an array of one million items no more than 20 items are checked. If a list of the entire world's population were to be searched using this algorithm, less than 40 checks are made to find any one person.

The binary search algorithm can be implemented recursively. The pseudocode for a recursive solution appears like:

```
if (goal == items[mid]) {
 return(mid)
} else if (goal < items[mid]) {
 return(binarySearch(lowerhalf))
} else {
 return(binarySearch(upperhalf))
}
```

The Searches class on the next page implements a binary search:

```

public class Searches{

 /**
 * Searches items array for goal
 * pre: items is sorted from low to high
 * post: Position of goal has been returned,
 * or -1 has been returned if goal not found.
 */
 public static int binarySearch(int[] items, int start,
 int end, int goal) {

 if (start > end) {
 return(-1);
 } else {
 int mid = (start + end) / 2;
 if (goal == items[mid]) {
 return(mid);
 } else if (goal < items[mid]) {
 return(binarySearch(items, start, mid-1, goal));
 } else {
 return(binarySearch(items, mid+1, end, goal));
 }
 }
 }
}

```

The TestSorts application has been modified to sort an array of integers and then prompt the user for a number to search for:

```

import java.util.Scanner;
import java.util.Random;

public class TestSorts {

 public static void displayArray(int[] array) {
 for (int i = 0; i < array.length; i++) {
 System.out.print(array[i] + " ");
 }
 System.out.println("\n");
 }

 public static void sortIntArray() {
 Scanner input = new Scanner(System.in);
 int numItems, searchNum, location;
 int[] test;
 Random rand = new Random();

 System.out.print("Enter number of elements: ");
 numItems = input.nextInt();

 /* populate and sort array */
 test = new int[numItems];
 for (int i = 0; i < test.length; i++) {
 test[i] = rand.nextInt(100);
 }
 Sorts.mergesort(test, 0, test.length - 1);
 System.out.println("Sorted:");
 displayArray(test);
 }
}

```

```

/* search for number in sorted array */
System.out.print("Enter a number to search for: ");
searchNum = input.nextInt();
while (searchNum != -1){
 location = Searches.binarySearch(test, 0,
 test.length-1, searchNum);
 System.out.println("Number at position: " + location);
 System.out.print("Enter a number to search for: ");
 searchNum = input.nextInt();
}
}

public static void main(String[] args) {
 sortIntArray();
}
}

```

The modified TestSorts application displays output similar to:

```

Enter number of elements: 10
Unsorted:
80 84 68 23 36 70 75 39 29 11

Sorted:
11 23 29 36 39 68 70 75 80 84

Enter a number to search for: 11
Number at position: 0
Enter a number to search for: 23
Number at position: 1
Enter a number to search for: 81
Number at position: -1
Enter a number to search for: 84
Number at position: 9
Enter a number to search for: 68
Number at position: 5
Enter a number to search for: -1

```

## Review: SearchLocations

Create a SearchLocations application that displays the positions examined during a binary search. The application output should look similar to:

|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1  | 4  | 4  | 7  | 10 | 13 | 15 | 16 | 24 | 24 | 25 | 25 | 27 | 27 | 30 | 30 | 30 |    |
| 49 | 50 | 51 | 52 | 53 | 54 | 54 | 54 | 55 | 55 | 57 | 57 | 58 | 64 | 69 | 74 | 78 | 79 |
| 85 | 86 | 86 | 88 | 89 | 96 | 96 | 96 | 97 | 97 | 98 |    |    |    |    |    |    |    |

```

Enter a number to search for: 55
Examining 24
Examining 37
Examining 30
Examining 27
Examining 28
Number at position: 28
Enter a number to search for:

```

## Review: ObjectsBinarySearch

Create an ObjectsBinarySearch application that implements a binary search on an array of objects. Test the search on an array of String objects.

## Review: BinarySearch2

Create a BinarySearch2 application that implements a nonrecursive binary search. The binary search algorithm can be implemented without recursion by doing the following:

- Enclose the method body with a `do-while` loop
- Replace the recursive calls with appropriate assignments to the values of `start` or `end`.

## Depth-First Searching

Many programs generate and search through a series of possibilities, such as:

- different paths through a maze
- different possible ways of making change
- different possible plays in a game
- different schedules for a student in a school
- different pixels reachable from an initial pixel

All these tasks can be solved through the recursive technique called *depth-first searching*. The depth-first searching algorithm works by searching from a given starting position, processing that position, and then (recursively) searching from all adjacent positions.

Depth-first searching can be illustrated in a DetectColonies application that allows a researcher to determine the number and size of distinct colonies of bacteria on a microscope slide. The slide has been converted to digital format, where a \* represents a cell that is part of a colony, and a - represents the background color of the slide. A slide file has the format:

First line: length of slide  
Second line: width of slide  
Remaining lines: slide data.

For example, a slide file could look similar to:

```
7
9

---*--*--
--***-*--
***--*--
**-*--*
---****-
---*--*--
```

Cells are considered to be part of the same colony if they touch horizontally or vertically. The example slide contains three colonies. Counting rows and columns starting from zero, one colony has a cell at (1, 3) and contains 9 elements. Another colony has four elements with a cell at (1, 6), and the third has eight elements with a cell at (4, 3). Note that the first and third colonies are considered separate because they touch across a diagonal but not horizontally or vertically.

The DetectColonies application analyzes the slide and displays the following output:

```
Colony at (1,3) with size 9
Colony at (1,6) with size 4
Colony at (4,3) with size 8
```

A depth-first search is appropriate here because once a colony cell is detected, all the possible directions for connected cells must be searched. If a connected cell is a colony cell, then all the possible directions for that cell must be searched, and so on. The basic idea is that, given a starting cell at (row, col) in a colony, the total number of connected cells in that colony can be found as:

```
1 for the starting cell
+ count of connected cells starting with (row+1, col)
+ count of connected cells starting with (row-1, col)
+ count of connected cells starting with (row, col+1)
+ count of connected cells starting with (row, col-1)
```

The latter four lines are recursive calls. To find the starting cells, each cell in the slide is tested with a nested `for` loop.

When implementing a depth-first search algorithm, code must be included to avoid infinite recursion. For example, a starting cell of (1, 3) generates a recursive call with cell (2, 3), which generates a call with (1, 3) again, which generates a call with (2, 3), and so on. For this application, a cell will be changed to the background color once it has been examined. This makes counting colonies a destructive algorithm.

The DetectColonies application can be modeled with a `Slide` class. The constructor will load the slide data into variable member `slideData`, which is a two-dimensional array appropriate for modeling the slide. Method members `displaySlide()` and `displayColonies()` will display the slide and determine the colonies. Member constants `COLONY` and `NON_COLONY` will represent \* and -.

The `displayColonies()` method checks each cell of the entire slide, and whenever a colony cell is encountered, `displayColonies()` determines the colony size and displays data about the colony. To determine the size, `displayColonies()` calls a private member method `collectCells()`, which changes a cell to the background once it is counted.

The `Slide` class is implemented on the next page:

```

import java.io.*;

public class Slide {
 private char COLONY = '*', NON_COLONY = '-';
 private char[][] slideData;

 /**
 * constructor
 * pre: Slide file contains valid slide data in the format:
 * first line: length of slide
 * second line: width of slide
 * remaining lines: slide data
 * post: Slide data has been loaded from slide file.
 */
 public Slide(String s) {

 try {
 File slideFile = new File(s);
 FileReader in = new FileReader(slideFile);
 BufferedReader readSlide = new BufferedReader(in);
 int length = Integer.parseInt(readSlide.readLine());
 int width = Integer.parseInt(readSlide.readLine());
 slideData = new char[length][width];
 for (int row = 0; row < length; row++) {
 for (int col = 0; col < width; col++) {
 slideData[row][col] = (char)readSlide.read();
 }
 readSlide.readLine(); //read past end-of-line
 }
 readSlide.close();
 in.close();
 } catch (FileNotFoundException e) {
 System.out.println("File does not exist or could not
 be found.");
 System.err.println("FileNotFoundException: "
 + e.getMessage());
 } catch (IOException e) {
 System.out.println("Problem reading file.");
 System.err.println("IOException: " + e.getMessage());
 }
 }

 /**
 * Determines a colony size
 * pre: none
 * post: All colony cells adjoining and including
 * cell (Row, Col) have been changed to NON_COLONY,
 * and count of these cells is returned.
 */
 private int collectCells(int row, int col) {

 if ((row < 0) || (row >= slideData.length) ||
 (col < 0) || (col >= slideData[0].length)
 || (slideData[row][col] != COLONY)) {
 return(0);
 } else {
 slideData[row][col] = NON_COLONY;
 return(1+
 collectCells(row+1, col) +
 collectCells(row-1, col) +
 collectCells(row, col+1) +
 collectCells(row, col-1));
 }
 }
}

```

```

 /**
 * Analyzes a slide for colonies and displays colony data
 * pre: none
 * post: Colony data has been displayed.
 */
 public void displayColonies() {
 char[][] temp;
 int count;

 for (int row = 0; row < slideData.length - 1; row++) {
 for (int col = 0; col < slideData[0].length; col++) {
 if (slideData[row][col] == COLONY) {
 count = collectCells(row, col);
 System.out.println("Colony at (" + row + "," + col
 + ") with size " + count);
 }
 }
 }
 }

 /**
 * Displays a slide.
 * pre: none
 * post: Slide data has been displayed.
 */
 public void displaySlide() {

 for (int row = 0; row < slideData.length; row++) {
 for (int col = 0; col < slideData[0].length; col++) {
 System.out.print(slideData[row][col]);
 }
 System.out.println();
 }
 }
}

```

The depth-first search algorithm is implemented in the helper method `collectCells()`. The first `if` statement checks to see that the current position is on the slide and contains a colony cell. This eliminates the need to check before each recursive call. As good programming style, it is better to check data at the start of the recursive function rather than before each call.

The `DetectColonies` application is relatively simple:

```

public class DetectColonies {

 public static void main(String[] args) {

 Slide culture = new Slide("slide.dat");
 culture.displaySlide();
 culture.displayColonies();
 }
}

```

The DetectColonies application displays output similar to:

```

---*---*-
---***-*-
***---*-

---***--*

Colony at (1,3) with size 9
Colony at (1,6) with size 4
Colony at (4,3) with size 8
```

## Review: DetectColonies – part 1 of 3

How must the DetectColonies application be modified if the definition of a colony allowed the colony to be connected across diagonals? What colonies would be reported by DetectColonies for the sample slide?

## Review: DetectColonies – part 2 of 3

Modify the DetectColonies application to display the slide colonies from largest to smallest.

## Review: DetectColonies – part 3 of 3

What slide will be output by the second `culture.displaySlide()` statement if DetectColonies contained the statements below? Explain.

```
public static void main(String[] args) {

 Slide culture = new Slide("slide.dat");
 culture.displaySlide();
 culture.displayColonies();
 culture.displaySlide();
}
```

## Algorithm Analysis

**TIP** Theoretical running times can be written in Big Oh notation, which is a theoretical measure of an algorithm's efficiency.

*Algorithm analysis* includes measuring how efficiently an algorithm performs its task. A more efficient algorithm has a shorter running time. *Running time* is related to the number of statements executed to implement an algorithm. It can be estimated by calculating statement executions. Running time estimations are usually based on a worst-case set of data. For example, an array that is already sorted or nearly sorted may require fewer statement executions than an array of data that is in reverse sorted order. Since the original state of the data is usually unknown, the worst case should be assumed.

As a first analysis, consider the selection sort algorithm, which uses nested `for` loops to sort items. If the sort is thought of in simplified terms, with each `for` statement containing a single statement, for an array of  $n$  items,  $n * n$  statements are executed. The selection sort is therefore said to have a running time of  $n^2$ .

The insertion sort algorithm seems more efficient because a `while` loop is used within a `for` loop. This could allow for a faster sort in some cases, but in the worst case, the insertion sort algorithm executes  $n$  statements \*  $n-1$  statements for a running time of about  $n^2$ .

The mergesort is a more complicated algorithm, but a divide and conquer approach can be much more efficient than a linear approach. Because this algorithm divides the array and each subarray in half until the base case of one element is reached, there are  $\log_2 n$  calls to `mergesort()` and then  $n$  calls to merge. The mergesort algorithm is said to have running time of  $n \log n$ .

The binary search also implements a divide and conquer approach. However, the elements are already ordered. The algorithm is simply performing a search. Because this algorithm divides the array and each subarray in half until the base case of one element is reached, there are  $\log_2 n$  calls to `binarySearch()`. Therefore, the algorithm is said to have a running time of  $\log_2 n$ .

## Chapter Summary

Sorting is the process of putting items in a designated order, either from low to high or high to low. The selection sort, insertion sort, and mergesort algorithms were presented in this chapter. The merge sort algorithm takes a divide-and-conquer approach to sorting. It is implemented recursively and is much faster than the selection and insertion sorts.

Objects cannot be compared with relational operators. Therefore, lists of objects are sorted by implementing an algorithm that uses the Comparable interface. Interfaces can be used as data types, which allows a generic implementation of an algorithm that sorts objects. Objects that are to be sorted must have a class that implements the Comparable interface.

A method can call itself in a process called recursion. Recursion is a programming technique that can be used whenever a problem can be solved by solving one or more smaller versions of the same problem and combining the results. To prevent infinite recursion, a base case that requires no recursion must be part of the recursive solution.

A binary search algorithm can be used to find an element in a sorted array. Binary search is implemented recursively and is very efficient. The depth-first searching algorithm can be used to search through a series of possibilities. When implementing depth-first searching, code must be included to avoid infinite recursion.

Algorithm analysis includes how efficiently an algorithm performs its task. A more efficient algorithm has a shorter running time.

## Vocabulary

**Binary search** A searching algorithm that recursively checks the middle of a sorted list for the item being searched for.

**Base case** The part of a recursive solution that requires no recursion.

**Depth-first search** A searching algorithm that recursively checks a starting position, processes that position, and then searches adjacent positions.

**Infinite recursion** A recursive solution which has no base case.

**Mergesort** A sorting algorithm that recursively divides a list into halves, sorting those halves, and then merging the lists so that the items are in order.

**Insertion sort** A sorting algorithm that repeatedly inserts an item into the appropriate position of a subarray until the subarray has no items left to insert.

**Recursion** The process in which a method calls itself. A programming technique that can be used whenever a problem can be solved by solving one or more smaller versions of the same problem and combining the results.

**Recursive call** A call to a method from within the same method.

**Selection sort** A sorting algorithm that repeatedly selects the lowest item in a subarray of an array and moves it to the position just before the subarray until the subarray has no items left to search.

## Java

**Comparable** A `java.lang` interface that is required to be implemented by a class if their objects are to be sorted. Comparable can also be used as a data type.

## Critical Thinking

1. For the list 4, 6, 2, 10, 9, show how the numbers are ordered after each loop iteration of the algorithms:

- a) selection sort
- b) insertion sort

2. What must be done to a list of items in order to use a binary search to find a specific item?

3. Use the recursive method below to answer the questions:

```
public void ct(int n) {
 System.out.println("Starting " + n);
 if (n > 0) {
 ct(n/3);
 System.out.println("Middle " + n);
 }
}
```

- a) What output is generated when `ct(13)` is called?
- b) What output is generated when `ct(3)` is called?
- c) What output is generated when `ct(0)` is called?

4. Use the recursive method below to answer the questions:

```
public void ct(int n) {
 System.out.println(n);
 if (n > 0) {
 if (n % 2 == 1) {
 ct(n/3);
 } else {
 ct(n/2);
 }
 }
}
```

- a) What output is generated when `ct(13)` is called?
- b) What output is generated when `ct(14)` is called?
- c) What output is generated when `ct(15)` is called?

5. Use the recursive method below to answer the questions:

```
public void ct(int n) {
 if (n > 0) {
 ct(n/10);
 System.out.println(n % 10);
 }
}
```

- a) What output is generated when `ct(13)` is called?
- b) What output is generated when `ct(124)` is called?
- c) What output is generated when `ct(21785)` is called?
- d) What in general does this method do?

6. Use the recursive method below to answer the questions:

```
public void whatzItDo() {
 Scanner input = new Scanner(System.in);
 String letter = input.next();
 if (!letter.equals(".")) {
 whatzItDo();
 System.out.print(letter);
 }
}
```

- a) What output is generated when the user enters T, E, S, T, . ?
- b) What in general does this method do?

7. A sorting algorithm is said to be “stable” if two items in the original array that have the same “key value” (the value to be sorted on) maintain their relative position in the sorted version. For example, assume an array with the following data:

| Ann | Jon | Mel | Tom | Kim |
|-----|-----|-----|-----|-----|
| 20  | 19  | 18  | 19  | 22  |

When the array is sorted by age, a stable sort would guarantee that Jon would stay ahead of Tom in the sorted array, as in:

| Kim | Ann | Jon | Tom | Mel |
|-----|-----|-----|-----|-----|
| 22  | 20  | 19  | 19  | 18  |

and not:

| Kim | Ann | Tom | Jon | Mel |
|-----|-----|-----|-----|-----|
| 22  | 20  | 19  | 19  | 18  |

Which of the sorts presented in this chapter (selection, mergesort) is stable? For each which is not stable, give an example of data to illustrate this.

**True/False**

8. Determine if each of the following are true or false. If false, explain why.
- a) Sorting always puts items in order from low to high.
  - b) One measure of the efficiency of a sorting algorithm is the speed at which it can complete a sort.
  - c) The selection sort algorithm is more efficient than the insertion sort.
  - d) A method can call itself.
  - e) The merge sort algorithm is more efficient than the selection sort algorithm for large arrays.
  - f) A binary search is used to sort a list of items.
  - g) A binary search starts by examining the last item in an array.
  - h) The more statements required to complete a task, the more efficient the algorithm.
  - i) An interface can be used as a data type.
  - j) A recursive solution that has no base case results in infinite recursion.
  - k) An insertion sort recursively divides a list into halves, sorting those halves, and then merging the lists in order.

## Exercises

### Exercise 1

### Friends

Create a Friends database application that maintains a file of Friend objects that contain names, telephone numbers, and email addresses. The Friends application should load Friend records from a file and then allow the user to add new friends, delete friends, display a list of all friends by either first name or last name, and search for a friend. The application should display a menu similar to:

1. Add a friend.
2. Display friends by last name.
3. Display friends by first name.
4. Find a friend.
5. Delete a friend.
6. Quit.

### Exercise 2

### TernarySearch

Modify the Searches class to include a ternarySearch() method. A ternary search, similar to a binary search, divides an array into three pieces rather than two. A ternary search finds the points that divide the array into three roughly equal pieces, and then uses these points to determine where the goal should be searched for.

### Exercise 3

### InterpolationSearch

Modify the Searches class to include an interpolationSearch() method. An interpolation search is a variation of the binary search. The idea is to look in a likely spot, not necessarily the middle of the array. For example, if the value sought is 967 in an array that holds items ranging from 3 to 1022, it would be intelligent to look nearly at the end of the array. Mathematically, because 967 is about 95% of the way from 3 to 1022, the position to start searching at is a position 95% of the way down the array. For example, if the array holds 500 elements, the first position to examined is 475 (95% of the way from 1 to 500). The search then proceeds to a portion of the array (either 1.474 or 476..500) depending upon whether 967 is greater or less than the 475th element.

### Exercise 4

### NumDigits

Create a NumDigits application that includes a recursive method numDigits() that returns the number of digits in its integer parameter. Numbers -9 through 9 have one digit; numbers -99 to -10 and 10 to 99 have two digits, and so on. (Hint: the number of digits of a number  $n$  is one more than the number of digits in  $n/10$ .)

## Exercise 5

## DetectColonies2

Create a DetectColonies2 application that is based on DetectColonies presented in this chapter. This application gives improved colony results because slides are now digitized to report color. For example, a slide file could look similar to:

```
6
8
00550000
00050000
00005500
01200000
01111000
00000030
```

The digits 1 through 9 represent various colors. The digit 0 represents black (background color).

The DetectColonies2 application should display a listing of the size, location, and color value of each colony on the slide. A colony is defined as a connected (horizontally or vertically) sequence of cells holding the same color value. For the above slide, the application should report:

| Color | Size | Location |
|-------|------|----------|
| 5     | 3    | 1, 3     |
| 5     | 2    | 3, 5     |
| 1     | 5    | 4, 2     |
| 2     | 1    | 4, 3     |
| 3     | 1    | 6, 7     |

## Exercise 6

## Knapsack

A well-known problem in computer science is called the *knapsack problem*. A variation is as follows:

Given a collection of weights of (possibly) different integral values, is it possible to place some of the weights in a knapsack so as to fill it to some exact total weight?

For example, if the weights are 3, 5, 6, and 9, then it is possible for such totals as 3, 8, 11, 14, 17, etc. to be made exactly, but 2, 4, 22, etc. are not possible.

Create a Knapsack application that solves this problem. The fillKnapsack() method handles the first weight, and then recursively handles the remaining weights with an isPossible() helper method. fillKnapsack() and isPossible() have the following declarations:

```
/* Returns true if there exists a subset of the items in
 * weights[start..weights.length] that sum to goal.
 * pre: items in weights[start..weights.length] > 0
 * post: true has been returned if there exists a subset
 * of items in weights[start..weights.length] that sum to goal.
 */
fillKnapsack(int[] weights, int goal, int start)
```

```

/*
 * Returns true if there exists a subset of the items in
 * weights that sum to goal.
 * pre: items in weights > 0
 * post: true has been returned if there exists a subset
 * of items in weight that sum to goal.
 */
isPossible(int[] weights, int goal)

```

The fillKnapsack algorithm determines if the goal can be found in all of the items not including the first, or if it can be found by including the first in the subset. The pseudocode is:

```

if (simple case) {
 handle simple cases
} else {
 if (fillKnapsack(weights, goal, start+1)) {
 return(true);
 } else if (fillKnapsack(weights, goal-weights[start], start+1)) {
 return(true);
 } else {
 return(false);
 }
}

```

Note that the simple cases will need to be determined and handled properly.

## Exercise 7

## Maze

A maze can be defined in a file using X characters to represent walls, space characters to represent paths, and a \$ character to represent the goal. For example, a file containing a maze could look similar to:

```

8
10
XXXXXXXXXX
X X
XX XXX XXX
XX X X
XXXX X X X
X X XXX
X XXXX $X
XXXXXXXXXX

```

The starting point is assumed to be location (1, 1) and the maze is assumed to have a border. Create a Maze application that displays the sequence of positions in a path from the start to the goal, or indicate if no path is available. For example, for the maze above, the application should report:

```

Path: (1,1) (1,2) (1,3) (1,4) (1,5) (1,6)
 (2,6) (3,6) (4,6) (5,6) (6,6) (6,7) (6,8)

```

## Exercise 8

## MyBoggle

The game of Boggle is played on a square board with random letters. The object is to find words formed on the board by contiguous sequences of letters. Letters are considered to be touching if they are horizontally, vertically, or diagonally adjacent. For example, the board:

|   |   |   |   |   |
|---|---|---|---|---|
| Q | W | E | R | T |
| A | S | D | F | G |
| Z | X | C | V | B |
| Y | U | A | O | P |
| G | H | J | K | L |

contains the words WAS, WAXY, JOB, and others, but not the word BOX. Words can contain duplicate letters, but a single letter on the board may not appear twice in a single word, for example POP is not contained on this board.

Create a MyBoggle application that displays a board of random letters, and allows the user to enter words found on the board. The application should report if the word entered by the user is indeed on the board.

Hint: Search the board for the first letter of the word entered, and then recursively search around the found letter for the remaining letters of the word.

# Chapter 14

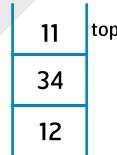
## Data Structures

**D**ata structures are discussed in this chapter. Stacks, queues, and linked lists are covered.

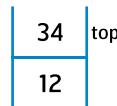
### The Stack Data Structure

A data structure organizes data. The *stack* data structure can contain many data items just as an array can. Additionally, it has a set of operations that can be performed on the data.

**top** A stack structure has a *top*. For example, the stack shown below holds three integers. The value 11 is the top item in the stack:

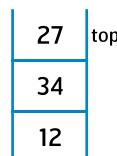


**pop** There are two standard operations that can be performed on the items in a stack, and only the top item of a stack can be processed. The *pop* operation removes the top item. For example, when a pop is executed on the stack above, the top value, 11, is removed:



The next item, 34, is now at the top of the stack, and is the only item that can be accessed.

**push** Another operation is the *push* operation, which adds an item to the top of the stack. For example, if the value 27 is pushed onto the stack, the stack becomes:



**isEmpty**  
**size**  
**makeEmpty**

Other stack operations include the *isEmpty* query, which returns true when there are no items in the stack, and false otherwise. The *size* operation determines the number of items in a stack. A stack can be emptied with the *makeEmpty* operation.

**LIFO**

Since the stack is designed so that the last item pushed on is the first item to be popped, it is sometimes referred to as a *last-in-first-out* (LIFO) data structure. There are a number of applications of stacks, particularly in writing compiler software. For example, each of the following is generally performed using a stack:

- Matching of braces, { and }. In Java, a close brace, }, always goes with the last open brace, {.
- Matching `else` with `if`: An `else` always goes with the last `if`.
- Matching of parentheses in an expression: A closing parenthesis always goes with the last open parenthesis.
- Recursion: After completion of a recursive call, control returns to the last call that was executed. In fact, recursion is sometimes replaced with a stack.

## The Stack Class

A data structure has a specific set of operations that can be performed on the data it stores. Therefore, a class is often used to implement the data structure.

The StackDemo application uses a stack:

```
public class StackDemo {

 public static void main(String[] args) {
 Stack s = new Stack(10);

 System.out.println("Adding 10 and 13 to stack.");
 s.push(10);
 s.push(13);
 System.out.println("Top of stack: " + s.top());
 System.out.println("Items in stack: " + s.size());
 System.out.println("Removing top item.");
 s.pop();
 System.out.println("Top of stack: " + s.top());
 System.out.println("Items in stack: " + s.size());
 System.out.println("Adding a new item.");
 s.push(40);
 System.out.println("Top of stack: " + s.top());
 System.out.println("Items in stack: " + s.size());
 }
}
```

The StackDemo produces the output:

```
Adding 10 and 13 to stack.
Top of stack: 13
Items in stack: 2
Removing top item.
Top of stack: 10
Items in stack: 1
Adding a new item.
Top of stack: 40
Items in stack: 2
```

The Stack class below is a very simple stack implementation that stores data in an array:

```
public class Stack {
 private int[] data;
 private int top;

 /**
 * constructor
 * pre: none
 * post: An empty stack that can hold up to maxItems
 * has been created.
 */
 public Stack(int maxItems) {
 data = new int[maxItems];
 top = -1; //no items in the array
 }

 /**
 * Returns the top item without removing it from the stack.
 * pre: Stack contains at least one item.
 * post: The top item has been returned while leaving it
 * on the stack.
 */
 public int top() {
 return(data[top]);
 }

 /**
 * Removes the top item from the stack and returns it.
 * pre: Stack contains at least one item.
 * post: The top item of the stack has been removed
 * and returned.
 */
 public int pop() {
 top -= 1;
 return(data[top + 1]);
 }
```

```

 /**
 * Adds an item to the top of the stack if there is room.
 * pre: none
 * post: A new item has been added to the top of the stack.
 */
 public void push(int num) {
 if (top < data.length - 1) {
 top += 1;
 data[top] = num;
 }
 }

 /**
 * Determines if there are items on the stack.
 * pre: none
 * post: true returned if there are items on the stack,
 * false returned otherwise.
 */
 public boolean isEmpty() {
 if (top == -1) {
 return(true);
 } else {
 return(false);
 }
 }

 /**
 * Returns the number of items in the stack.
 * pre: none
 * post: The number of items in the stack is returned.
 */
 public int size() {
 if (isEmpty()) {
 return(0);
 } else {
 return(top + 1);
 }
 }

 /**
 * Empties the stack.
 * pre: none
 * post: There are no items in the stack.
 */
 public void makeEmpty() {
 top = -1;
 }
}

```

The Stack class implements a stack for `int` values. A generic implementation would use objects. This implementation is completed in the Stack2 review.

## Review: Stack2

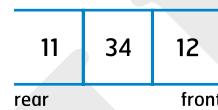
Create a Stack2 class that implements a stack data structure for data type Object. Since Object is the super-class of other objects, a Stack2 object can store objects from any class. Write appropriate client code to test the Stack2 class.

## Review: Stack3

The Stack class is limited because the stack size cannot change from its initial size. Create a Stack3 class that implements a stack data structure using an ArrayList. Write appropriate client code to test the Stack3 class.

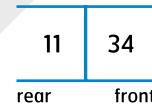
## The Queue Data Structure

A *queue* is a data structure similar to a stack in that it holds a number of data items. However, one end of the queue is referred to as the *rear* and the other end the *front*. For example, the queue shown below holds three items:

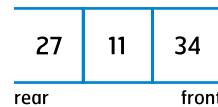


All insertions are made at the rear and all removals are made at the front.

There are two standard operations that can be performed on a queue. The *dequeue* operation removes an item from the front. For example, when a dequeue is executed on the queue above, the value at the front, 12, is removed from the queue:



The *enqueue* operation adds an item to the rear of the queue. For example, if the value 27 is enqueued, the queue becomes:



Other queue operations include the *front* operation, which returns the front item without removing it from the queue. The *isEmpty* query returns true when there are no items in the queue, and false otherwise. The *size* operation determines the number of items in a queue. A queue can be emptied with the *makeEmpty* operation.

A queue is analogous to a line at a ticket counter where “first come, first served,” and is sometimes referred to as a *first in first out* (FIFO) data structure. There are a number of real-world situations that can be represented as a queue structure. For example:

- Lines at a toll booth or bank teller
- Waiting lists for tickets on planes
- Pages of data queued up for a printer
- Performing breadth-first-searching where all items near the starting position are examined before looking at those farther away.

## The Queue Class

The QueueDemo application uses a queue:

```
public class QueueDemo {

 public static void main(String[] args) {
 Queue q = new Queue(10);

 System.out.println("Adding 10 and 13 to queue.");
 q.enqueue(10);
 q.enqueue(13);
 System.out.println("Front of queue: " + q.front());
 System.out.println("Items in queue: " + q.size());
 System.out.println("Dequeuing front item.");
 q.dequeue();
 System.out.println("Front of queue: " + q.front());
 System.out.println("Items in queue: " + q.size());
 System.out.println("Queueing a new item.");
 q.enqueue(40);
 System.out.println("Front of queue: " + q.front());
 System.out.println("Items in queue: " + q.size());
 }
}
```

The QueueDemo produces the output:

```
Adding 10 and 13 to queue.
Front of queue: 10
Items in queue: 2
Dequeuing front item.
Front of queue: 13
Items in queue: 1
Queueing a new item.
Front of queue: 13
Items in queue: 2
```

The Queue class below is a very simple queue implementation that stores data in an array:

```
public class Queue {
 private int[] data;
 private int front, rear, maxSize;
```

```

 /**
 * constructor
 * pre: none
 * post: An empty queue that can hold up to maxItems
 * has been created.
 */
 public Queue(int maxItems) {
 data = new int[maxItems];
 front = -1; //no items in the array
 rear = -1;
 maxSize = maxItems;
 }

 /**
 * Returns the front item without removing it from
 * the queue.
 * pre: Queue contains at least one item.
 * post: The front item has been returned while leaving
 * it in the queue.
 */
 public int front() {
 return(data[front]);
 }

 /**
 * Removes the front item from the queue and returns it.
 * pre: Queue contains at least one item.
 * post: The front item of the queue has been removed
 * and returned.
 */
 public int dequeue() {
 front = (front + 1) % maxSize;
 return(data[front - 1]);
 }

 /**
 * Adds an item to the queue if there is room.
 * pre: none
 * post: A new item has been added to the queue.
 */
 public void enqueue(int num) {
 if (isEmpty()) { //first item queued
 rear = 0;
 front = 0;
 data[rear] = num;
 } else {
 rear = (rear + 1) % maxSize;
 data[rear] = num;
 }
 }

```

```

 /**
 * Determines if there are items on the queue.
 * pre: none
 * post: true returned if there are items on the queue,
 * false returned otherwise.
 */
 public boolean isEmpty() {
 if (front == -1 && rear == -1) {
 return(true);
 } else {
 return(false);
 }
 }

 /**
 * Returns the number of items in the queue.
 * pre: none
 * post: The number of items in the queue is returned.
 */
 public int size() {
 if (isEmpty()) {
 return(0);
 } else {
 return(rear - front + 1);
 }
 }

 /**
 * Empties the queue.
 * pre: none
 * post: There are no items in the queue.
 */
 public void makeEmpty() {
 front = -1;
 rear = -1;
 }
}

```

Because the queue is limited to the number of items it can store, the front and rear pointers must cycle through the spots available in the array. Therefore, the front and rear values are calculated using modular arithmetic (%).

The Queue class implements a queue for `int` values. A generic implementation would use objects. This implementation is left as a review.

## Review: Queue2

Create a Queue2 class that implements a queue data structure for data type Object. Since Object is the super-class of other objects, a Queue2 object can store objects from any class. Write appropriate client code to test the Object2 class.

## Review: Queue3

The Queue class is limited because the queue size cannot change from its initial size. Create a Queue3 class that implements a queue data structure using an ArrayList. Write appropriate client code to test the class.

# The Linked List Data Structure

Another way of storing lists of data in memory requires each item to store information that indicates where the next item is stored. The additional information is a reference, or pointer, to a data location. This kind of list data structure is called a *linked list*, and can be illustrated like:



**head, tail  
node**

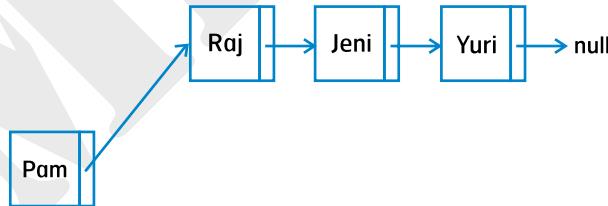
**TIP** Objects stored in memory are stored in dynamic memory. Dynamic memory is allocated from an area called the *heap*, which is used during program execution.

**addAtFront**

The first item in a linked list is called the *head*. The last item points to null and is called the *tail*. Each element of a linked list is called a *node*. There are three nodes in the list above.

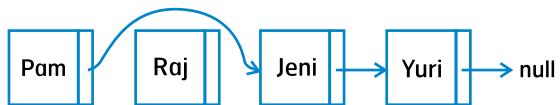
Because each item in a linked list must contain data and a pointer, an item is best modeled with a class. Therefore, a linked list is a list of objects. The objects in a linked list are organized because they point to each other. There is no need to place them in a structure, such as an array, for organization. This means that linked links are not restricted by the size of an array.

There are two standard operations that can be performed on a linked list. The *addAtFront* operation adds a new node to the front of the list. When a new node is added to the front of a linked list, it is simply designated the head and its pointer is set to the current head. For example, if Raj was the head, adding a new item means that the new object is now the head and its pointer points to the Raj object:



**remove**

The *remove* operation removes an item from the linked list. Removing an item from a linked list means that the pointer of the previous item is changed to point to the item after the one to be removed. For example, removing Raj from the list below means that the object is no longer referenced by another object in the list:



Linked lists are useful for maintaining dynamic lists because the number of items in a linked list can shrink and grow as needed.

# The LinkedList Class

The LinkedListDemo application uses a linked link:

```
public class LinkedListDemo {

 public static void main(String[] args) {
 LinkedList list = new LinkedList();

 list.addAtFront("Sachar");
 list.addAtFront("Osborne");
 list.addAtFront("Suess");
 System.out.println(list);

 list.remove("Suess");
 list.remove("Sachar");
 list.remove("Osborne");
 System.out.println(list);
 }
}
```

The LinkedListDemo produces the output:

```
Suess
Osborne
Sachar
```

```
There are no items in list.
```

## nested class

## outer class

The LinkedList class below contains a nested class. A *nested class* is a class within a class. A nested class is a member of the class it is within. As a class member, it has access to all the other members of the class, including private member variables and methods. A class that contains a class member is called an *outer class*. The Node class is a nested class because its members should only be accessed by a LinkedList object:

```
public class LinkedList {
 private Node head;

 /**
 * constructor
 * pre: none
 * post: A linked list with a null item has been created.
 */
 public LinkedList() {
 head = null;
 }

 /**
 * Adds a node to the linked list.
 * pre: none
 * post: The linked list has a new node at the head.
 */
 public void addAtFront(String str) {
 Node newNode = new Node(str);
 newNode.setNext(head);
 head = newNode;
 }
}
```

```

 /**
 * Deletes a node in the linked list.
 * pre: none
 * post: The first node containing str has been deleted.
 */
 public void remove(String str) {
 Node current = head;
 Node previous = head;

 if (current.getData().equals(str)) {
 head = current.getNext();
 } else {
 while (current.getNext() != null) {
 previous = current;
 current = current.getNext();
 if (current.getData().equals(str)) {
 previous.setNext(current.getNext());
 }
 }
 }
 }

 /**
 * Creates a string that lists the nodes of the
 * linked list.
 * pre: none
 * post: The linked list has been written to a string.
 */
 public String toString() {
 Node current = head;
 String listString;

 if (current != null) {
 listString = current.getData() + "\n";
 while (current.getNext() != null) {
 current = current.getNext();
 listString += current.getData() + "\n";
 }
 return(listString);
 } else {
 return("There are no items in list.");
 }
 }

 private class Node {
 private String data;
 private Node next;

 /**
 * constructor
 * pre: none
 * post: A node has been created.
 */
 public Node(String newData) {
 data = newData;
 next = null;
 }
 }
}

```

**TIP** Nested classes were also introduced in Chapter 11.

```

 /**
 * The node pointed to by next is returned
 * pre: none
 * post: A node has been returned.
 */
 public Node getNext() {
 return(next);
 }

 /**
 * The node pointed to by next is changed to newNode
 * pre: none
 * post: next points to newNode.
 */
 public void setNext(Node newNode) {
 next = newNode;
 }

 /**
 * The node pointed to by next is returned
 * pre: none
 * post: A node has been returned.
 */
 public String getData() {
 return(data);
 }
}

```

## Review: LinkedList – part 1 of 3

Modify the LinkedList class to include a member function size() that returns the number of items in the list.

## Review: LinkedList – part 2 of 3

Modify the LinkedList class to include a member function addAtEnd() that adds a new item to the end of the linked list.

## Review: LinkedList – part 3 of 3

Modify the LinkedList class to include a member function makeEmpty() that removes all the items in the list

## Chapter Summary

The stack, queue, and linked list data structures were introduced in this chapter. Each data structure organizes data and can be used to perform a set of operations on that data.

The stack data structure is also called a LIFO structure because the last item in is the first item out. A stack has a top. Operations that can be performed on a stack include pop, push, isEmpty, size, and makeEmpty.

The queue data structure is also called a FIFO structure because the first item in is the first item out. A queue has a front and rear. Operations that can be performed on a queue include enqueue, dequeue, isEmpty, size, and makeEmpty.

The linked list data structure is a list of objects that point to each other. The linked list does not have the size limitations of a data structure implemented using an array. A linked list has a head and a tail. Each item in a linked list is called a node. Operations that can be performed on a linked list include addAtFront and remove.

## Vocabulary

**addAtFront** A linked list operation where an item is added to the front of the list.

**Dequeue** A queue operation that removes the item at the front of the queue.

**Enqueue** A queue operation that adds an item to the rear of the queue.

**FIFO** First In First Out. A queue data structure.

**Front** The start of a queue.

**Head** The first node in a linked list.

**isEmpty** A stack or queue operation that returns true when there are no items in the data structure and false otherwise.

**LIFO** Last In First Out. A stack data structure.

**Linked list** A data structure that has a head and tail and contains nodes that point to each other.

**Nested class** A class that is a member of another class. A class within a class.

**Node** A linked list element. A node contains the item and a pointer to the next node.

**Outer class** A class that contains a class member.

**Pop** A stack operation where the top item is removed.

**Push** A stack operation where a new item is added.

**Queue** A data structure that has a front and rear and organizes data so that the first item in is the first item out.

**Rear** The end of a queue.

**Remove** A linked list operation where an item is removed from the list.

**Size** A stack or queue operation that returns the number of items in the data structure.

**Stack** A data structure that has a top and organizes data so that the last item in is the first item out.

**Tail** The last node in a linked list. The tail points to null.

**Top** The last item pushed onto a stack.

## Critical Thinking

1. Explain the similarities between an array and a stack.
2. Describe how a programmer might use a stack when writing compiler software.
3. What output is generated by the following statements if `s` is a Stack object?

```
Stack s = new Stack(10);
s.push(5);
s.push(8);
int x = s.pop();
s.push(x);
s.push(12);
s.push(13);
int y = s.pop();
System.out.println(x + " " + y);
y = s.pop();
x = s.top();
System.out.println(x + " " + y);
```

4. Consider the “hot plate” problem: In a busy restaurant, fresh salad plates are brought out and added to the existing pile of plates. This means that, even though there may be plates that were washed long ago, the customer is frequently stuck with a warm plate for salad. Explain how this is analogous to a stack.
5. What output is generated by the following statements if `q` is a Queue object?

```
Queue q = new Queue(10);
q.enqueue(5);
q.enqueue(8);
int x = q.dequeue();
q.enqueue(x);
q.enqueue(12);
q.enqueue(13);
int y = q.dequeue();
System.out.println(x + " " + y);
y = q.dequeue();
x = q.front();
System.out.println(x + " " + y);
```

6. Explain the difference between a FIFO and a LIFO data structure.
7. List two real-world situations that could be represented as a queue structure other than those listed in the chapter.

### True/False

8. Determine if each of the following are true or false. If false, explain why.
  - A stack data structure has a front and a rear.
  - A stack can be emptied.
  - In a stack, top refers to the first item pushed onto a stack.
  - The isEmpty operation returns an `int` value.
  - A queue can hold more than one data item.
  - In a queue, all removals are made at the rear.
  - The enqueue operation adds an item to the front of the queue.
  - The first item in a linked list is called the head.
  - A node refers to an item in a stack.
  - The number of items in a stack or queue can be determined with the length operation.
  - In a linked list, the tail points to `null`.

## Exercises

### Exercise 1

### StackList

The Stack class implemented a stack using an array. A stack can also be implemented using a linked list. Create a StackList class that implements a stack using a linked list that can store Object data. The StackList class should implement the standard stack operations. Note that the standard linked list operations will not be implemented when the linked list is implementing a stack. What are the advantages or disadvantages of using a linked list rather than an array?

### Exercise 2

### ReverseList

Create a ReverseList application that uses a stack to reverse a set of integers entered by the user. The user should be prompted to enter up to 10 numbers or to terminate the list of numbers by entering 999. Application output should look similar to:

```
Enter a number (999 to quit): 10
Enter a number (999 to quit): 25
Enter a number (999 to quit): 44
Enter a number (999 to quit): 16
Enter a number (999 to quit): 999
The list reversed is: 16 44 25 10
```

### Exercise 3

### ParenChecker

To analyze an expression with parentheses, the computer must be able to determine which left parenthesis any given right parenthesis matches.

- Create a ParenChecker application that prompts the user to enter an expression with parentheses, and then displays a list of the positions of pairs of parentheses. The application should store the positions of the left parentheses on a stack when they are found. Application output should look similar to:

```
Enter an expression: (a-b*(c-d))
Pair: 10 6
Pair: 11 1
```

- Modify the ParenChecker application to detect the two errors below and display appropriate error messages:
  - Attempt to pop an empty stack.
  - Stack not empty at the end of the program.

## Exercise 4

## QueueList

The Queue class implemented a queue using an array. A queue can also be implemented using a linked list. Create a QueueList class that implements a queue using a linked list that can store Object data. The QueueList class should implement the standard queue operations. Note that the standard linked list operations will not be implemented when the linked list is implementing a queue. What are the advantages or disadvantages of using a linked list rather than an array?

## Exercise 5

## Stats

- a) Create a Stats interface that declares methods sum(), min(), and max(). The member methods should return an `int` value that represents the sum of the items in a list, the minimum value in a list, and the maximum value in a list.
- b) Create a LinkedList class that implements the Stats interface and stores `int` values. Write client code that tests the modified class.

## Exercise 6

## DoublyLinkedList

The nodes in a doubly-linked list point to the next and previous nodes, and can be thought of as:



The node of the doubly-linked list may be represented as:

```
private class Node {
 private String data;
 private Node next;
 private Node prev;
...rest of class
```

The previous field of the head is set to `null`.

- a) What advantages does this structure offer? What disadvantages?
- b) Compare the doubly-linked list with the singly linked list implemented in this chapter. When would you choose to use one rather than the other?
- c) Create a DoublyLinkedList class. Include member methods addAtFront(), addAtEnd(), remove(), and displayList() and displayReverseList().

# Appendix A

## Unicode

**E**very letter of an alphabet (Latin, Japanese, Cherokee, and so on) and symbols of every culture (=, @, ½, and so on) have been given a representation in a digital code called Unicode. Unicode uses a set of sixteen 1s and 0s to form a 16-bit binary code for each symbol. For example, the uppercase letter V is Unicode 00000000 01010110, which can be thought of as the base 10 number 86 (8610). Lowercase v has a separate code of 00000000 01110110, or 11810. Below is a table of some Unicode symbols and their corresponding decimal and binary equivalents.

| Decimal | Binary            | Unicode Symbol | Decimal | Binary            | Unicode Symbol | Decimal | Binary            | Unicode Symbol |
|---------|-------------------|----------------|---------|-------------------|----------------|---------|-------------------|----------------|
| 32      | 00000000 00100000 | space          | 64      | 00000000 01000000 | @              | 96      | 00000000 01100000 | `              |
| 33      | 00000000 00100001 | !              | 65      | 00000000 01000001 | A              | 97      | 00000000 01100001 | a              |
| 34      | 00000000 00100010 | "              | 66      | 00000000 01000010 | B              | 98      | 00000000 01100010 | b              |
| 35      | 00000000 00100011 | #              | 67      | 00000000 01000011 | C              | 99      | 00000000 01100011 | c              |
| 36      | 00000000 00100100 | \$             | 68      | 00000000 01000100 | D              | 100     | 00000000 01100100 | d              |
| 37      | 00000000 00100101 | %              | 69      | 00000000 01000101 | E              | 101     | 00000000 01100101 | e              |
| 38      | 00000000 00100110 | &              | 70      | 00000000 01000110 | F              | 102     | 00000000 01100110 | f              |
| 39      | 00000000 00100111 | '              | 71      | 00000000 01000111 | G              | 103     | 00000000 01100111 | g              |
| 40      | 00000000 00101000 | (              | 72      | 00000000 01001000 | H              | 104     | 00000000 01101000 | h              |
| 41      | 00000000 00101001 | )              | 73      | 00000000 01001001 | I              | 105     | 00000000 01101001 | i              |
| 42      | 00000000 00101010 | *              | 74      | 00000000 01001010 | J              | 106     | 00000000 01101010 | j              |
| 43      | 00000000 00101011 | +              | 75      | 00000000 01001011 | K              | 107     | 00000000 01101011 | k              |
| 44      | 00000000 00101100 | ,              | 76      | 00000000 01001100 | L              | 108     | 00000000 01101100 | l              |
| 45      | 00000000 00101101 | -              | 77      | 00000000 01001101 | M              | 109     | 00000000 01101101 | m              |
| 46      | 00000000 00101110 | .              | 78      | 00000000 01001110 | N              | 110     | 00000000 01101110 | n              |
| 47      | 00000000 00101111 | /              | 79      | 00000000 01001111 | O              | 111     | 00000000 01101111 | o              |
| 48      | 00000000 00110000 | 0              | 80      | 00000000 01010000 | P              | 112     | 00000000 01101000 | p              |
| 49      | 00000000 00110001 | 1              | 81      | 00000000 01010001 | Q              | 113     | 00000000 01110001 | q              |
| 50      | 00000000 00110010 | 2              | 82      | 00000000 01010010 | R              | 114     | 00000000 01110010 | r              |
| 51      | 00000000 00110011 | 3              | 83      | 00000000 01010011 | S              | 115     | 00000000 01110011 | s              |
| 52      | 00000000 00110100 | 4              | 84      | 00000000 01010100 | T              | 116     | 00000000 01110100 | t              |
| 53      | 00000000 00110101 | 5              | 85      | 00000000 01010101 | U              | 117     | 00000000 01110101 | u              |
| 54      | 00000000 00110110 | 6              | 86      | 00000000 01010110 | V              | 118     | 00000000 01110110 | v              |
| 55      | 00000000 00110111 | 7              | 87      | 00000000 01010111 | W              | 119     | 00000000 01110111 | w              |
| 56      | 00000000 00111000 | 8              | 88      | 00000000 01011000 | X              | 120     | 00000000 01111000 | x              |
| 57      | 00000000 00111001 | 9              | 89      | 00000000 01011001 | Y              | 121     | 00000000 01111001 | y              |
| 58      | 00000000 00111010 | :              | 90      | 00000000 01011010 | Z              | 122     | 00000000 01111010 | z              |
| 59      | 00000000 00111011 | ;              | 91      | 00000000 01011011 | [              | 123     | 00000000 01111011 | {              |
| 60      | 00000000 00111100 | <              | 92      | 00000000 01011100 | \              | 124     | 00000000 01111100 |                |
| 61      | 00000000 00111101 | =              | 93      | 00000000 01011101 | ]              | 125     | 00000000 01111101 | }              |
| 62      | 00000000 00111110 | >              | 94      | 00000000 01011110 | ^              | 126     | 00000000 01111110 | ~              |
| 63      | 00000000 00111111 | ?              | 95      | 00000000 01011111 | _              |         |                   |                |

SAMPLE

# Index

## Symbols

! 112  
!= 105  
" 63  
% 83  
%= 86  
&& 112  
\* 78, 81, 83  
\*<sup>=</sup> 86  
+ 83, 138  
    toString() 187  
++ 135  
+= 86  
-- 135  
. 80, 81  
.class extension 62  
.java extension 62  
/ 83  
/\*\* \*/ 62, 164  
/\* \*/ 62  
// 62  
/= 86  
< 105  
<!--comment--> 46  
<= 105  
<a> 48  
<applet> 44  
<body> 37  
<br> 46, 334  
<h1> 46  
<h2> 46  
<h3> 46  
<h4> 46  
<h5> 46  
<h6> 46  
<head> 37  
<hr> 46, 334  
<html> 37  
<img> 48  
<li> 46  
<object> 44  
<ol> 47  
<p> 46, 334  
<script> 38  
<table> 48  
<title> 37

<ul> 46  
= 78, 86  
== 105  
    comparing objects 186  
> 105  
>= 105  
[] 239, 248  
\ 63  
\\" 63  
\\\ 63, 312  
\n 63  
\t 63  
\} 61  
|| 112  
- 83  
-= 86  
3GL 5  
4GL 5  
802.11 network 8

**A**

abs(), Math class 113  
abstract class 222  
abstract data type 80  
abstract keyword 222  
abstract method 222  
Abstract Windows Toolkit 280  
accessibility 44  
accessor method 182  
access level, method 159  
access modifier 159  
acos(), Math class 130  
ActionListener interface 280  
action command 279  
ActiveX 44  
add(), ArrayList class 252  
add(), JPanel class 276  
addActionListener(), JButton 278  
addActionListener(), JComboBox  
    288  
addActionListener(), JTextField 285  
addAtFront, linked list 373  
addition 83  
address 10  
address bus 2

algorithm 66  
    design 66  
    stable 359  
algorithm analysis 356  
algortihm analysis 246  
alignment, Swing API 282  
ALU 2  
Amaya 35  
AMD 2  
anchor tag 48  
And 112  
    evaluation 113  
antivirus software 21  
appending data to a file 317  
applets 41, 43  
    adding color 43  
    drawing shapes 43  
    parameters 44  
    placing in an HTML document  
    44  
appletviewer 42  
application, terminating gracefully  
    312  
applications software 2  
argument 63, 160  
    object 161  
    passed by value 161  
    primitive data type 161  
ArithmaticException 89  
Arithmetric Logic Unit 2  
array 239  
    algorithm 242  
    characters 244  
    data structure 239  
    dynamic 252  
    element 239  
    initializing 240  
    length 240  
    offset indexes 243  
    parameter 241, 248  
    reference data type 242  
    traversing 240  
    two-dimensional 247  
ArrayIndexOutOfBoundsException  
    240, 241

ArrayList, data structure analysis 252  
ArrayList class 252  
array element 239  
    accessing 240  
    assigning a new value 240  
artificial intelligence 5  
ASCII 10  
asin(), Math class 130  
assembly language 5  
assignment 78, 86  
    array element 240  
    constant 87  
    variable 78  
atan(), Math class 130  
attributes 46  
auxiliary storage 12  
awt 280

## B

backslash character in a string 63  
backslash for escape sequence 63  
backup copy 21  
backup tools 4  
behavior of an object 179  
bandwidth 7  
base 10 logarithm 128  
base class 214  
Basic 5  
Big Oh notation 246, 252, 356  
binary files 11  
binary number system 9  
binary search 152, 349  
binary search algorithm analysis 357  
BIOS 2  
bit 9  
blog 15  
Bluetooth 4  
boolean 79, 106  
Boolean class 253  
Boolean expression 105, 131  
    evaluation 113  
Boolean logic 17  
border, Swing API 281  
boundary value 168  
BoxLayout manager, Swing API 282  
breadth-first-searching 370  
breakpoint 136  
break statement 109  
broadcast radio 7  
buffer 314  
BufferedReader(), BufferedReader class 314  
BufferedReader class 314  
BufferedWriter(), BufferedWriter class 318  
BufferedWriter class 317, 318  
bug 136  
built-in data types 79  
bus 2, 7

bus topology 7  
button, Swing API 278  
    for displaying an image 292  
byte 9, 79  
bytecode 62  
    converting to machine code 62  
Byte class 253

## C

C 5  
C++ 6, 62  
cable modem 14  
cache 2  
calling a method 159  
carpal tunnel syndrome 19  
carriage return character 314  
case clause 109  
case sensitivity, identifiers 88  
casting, see type casting 85  
CD-R 12  
CD-RW/DVD drive 1  
cellular radio 7  
Central Processing Unit 2  
chaos theory 154  
char 79, 244  
    array 244  
Character class 253  
charAt(), String class 244  
char array, initializing 245  
Children's Online Privacy Protection Act of 1998 18  
circuit boards 1  
citations 18  
class 59  
    abstract 222  
    base 214  
    body 180  
    constructor 182  
    declaration 180  
    derived 214  
    designing 180  
    extending 213  
    inner 188, 295  
    naming 181  
    nested 188, 295, 374  
    outer 295, 374  
    variables 180, 184  
    wrapper 253  
    writing 180  
class, objects to be written to a file 322  
ClassCastException 186  
classes using classes 187  
ClassNotFoundException 322  
class method 159, 184  
client/server network 7  
client code 180  
close() 81  
close(), BufferedReader class 314  
close(), BufferedWriter class 318  
close(), FileInputStream class 320

close(), FileOutputStream class 319  
close(), FileReader class 314  
close(), FileWriter class 317  
close(), ObjectInputStream class 321  
close(), ObjectOutputStream class 320  
coaxial cable 7  
COBOL 5  
code convention  
    variable identifier 77  
code conventions 65  
collection 252  
collections framework 252  
colors, Swing API 291  
combo box, Swing API 288  
comments 46, 61, 62  
    block 62  
    documentation 62, 164  
    for debugging 137  
    inline 108  
    method 164  
    multiline 62  
    postcondition documentation 164  
    precondition documentation 164  
    single line 62  
Communications Privacy Act of 1986 22  
communications satellites 7  
Comparable interface 225, 339  
compareTo(), Comparable interface 225  
compareTo(), Double class 254  
compareTo(), Integer class 253  
compareTo(), String class 140  
compareTo(), when sorting 339  
compareIgnoreCase(), String class 140  
compiler 5, 62  
    just-in-time 62  
    method overloading 162  
compiling source code 62  
compound interest 103  
compression program 11  
computers  
    desktop 1  
    handhelds 5  
    notebook 4  
    wearable 5  
    wrist-top 5  
computer vision syndrome 19  
concatenation 138  
    toString() 187  
conditional control structure 105, 109  
constant 87  
constructor 180, 183  
    subclass 215  
    writing 183

container, Swing 275  
 content frame, Swing 275  
 controlling class 61  
     Swing application 278  
 control bus 2  
 conventional modem 14  
 conversion, numeric 84  
 cookie 18  
 copyright 20  
 copyright infringement 21  
 $\cos()$ , Math class 130  
 counter 133  
 counting values 133  
 CPU 2  
 crackers 21  
`createNewFile()`, File class 311  
 cross-platform connectivity 5

## D

data  
     boundary values 168  
     passing to a method 160  
     processing 81  
     processing from a file 316  
     reading from a file 314  
     reading objects from a file 319  
     testing a method 168  
     writing objects to a file 319  
     writing to a file 317  
 data structure  
     array 239  
     ArrayList 252  
 data structures 365  
     linked list 373  
     queue 369  
     stack 365  
 data structure analysis  
     ArrayList 252  
 data type 77  
     abstract 80  
     interface 339  
     primitive 79  
 debugger 136  
 debugging 111, 136  
     commenting out statements 137  
     debugger 136  
     variable trace 136  
     with `println()` 137  
 Debug Window 136  
 decision structure 105, 109  
 declaration  
     array 239  
     class 180, 214  
     method 159  
     two-dimensional array 248  
     variable 77  
 decrement operator 135  
 Default package name 61  
`delete()`, File class 311  
 depth-first searching 352

dequeue, queue 369  
 derived class 214  
 desktop computer 1  
 device driver 4  
 digital camera 1  
 digital signature 15  
 Digital Subscriber Line 14  
 disk defragmentation 4  
 disk drive 1  
 divide-and-conquer 152, 345, 349  
 division 83  
     integer 83  
     modulus 83  
     real 83  
     type casting 85  
 do-while 131  
 documentation  
     comments 62  
     external 62  
     package 80  
     postcondition comments 164  
     precondition comments 164  
 documentation comments 164  
 Double 254  
 double 79  
`doubleValue()`, Double class 254  
 Double class 285  
 downloading 17  
 DSL 14  
 DVD drive 13  
 dynamic array 252  
 dynamic lists 373  
 dynamic memory 373

## E

e, natural logarithm 128  
 E-FOIA 18  
 e-mail 15  
     address 15  
     attachments 21  
     composition 16  
     etiquette 16  
     protocol 16  
 EBCDIC 10  
 ECPA 18  
 Electronic Communications Privacy  
     Act of 1986 18, 21  
 Electronic Freedom of Information  
     Act of 1996 18  
 electronic mail 15  
 element  
     array 239  
     ArrayList 252  
     ArrayList, adding 252  
     ArrayList, finding 252  
     ArrayList, removing 252  
 employee monitoring 19  
 encapsulation 59, 179, 182  
 encryption 19  
`endsWith()`, String class 140

end of file 314  
 enqueue, queue 369  
 environment 3  
     distributed 3  
     multiprocessing 3  
     multitasking 3  
     multiuser 3  
 environmental concerns 19  
`equals()` 186  
`equals()`, String class 140  
`equals()`, use by ArrayList 252  
`equals()` versus `==` 186  
`equalsIgnoreCase()`, String class 140  
 equal sign 78  
 ergonomics 19  
 error 62, 89  
     exception handling 312  
     logic 89  
     roundoff 106  
     run time 89, 240  
     semantic 89  
     syntax 62, 88, 132  
 err stream 313  
 escape sequence 63, 312  
 Ethernet 7  
 ethical implications of computer  
     use 19  
 ethical responsibilities, IT  
     professional 22  
 ethical responsibilities of an IT  
     professional 22  
 Euclid's Algorithm 153  
 Eudora 15  
 event 275  
 event-driven application 275  
 event handler 275  
 exabyte 13  
 exception 81, 89, 312  
     array 240  
     handling 89  
 exception handler 312  
 execution  
     program 62  
`exists()`, File class 311  
`exp()`, Math class 128  
 expansion boards 1  
 expectations vii  
 exponent 10  
 exponentiation 113  
 extends keyword 214  
 extension 11  
 extranet 13

## F

factorial 136  
 Fair Credit Reporting Act of 1970  
     20  
 false 79  
 fiber optic cable 7

file 11, 311  
creating 317  
HTML 37, 334  
processing numeric data 316  
reading 314  
stream 313  
writing to 317  
File(), File class 311  
FileInputStream(), FileInputStream class 320  
FileInputStream class 319, 320  
FileNotFoundException 315, 322  
FileOutputStream(),  
    OutputStream class 319  
FileOutputStream class 319  
FileReader(), FileReader class 314  
FileReader class 314  
files  
    organizing 181  
FileWriter(), FileWriter class 317  
FileWriter class 317  
File class 311  
file organization 61  
file position 313  
file size 11  
final 87  
Financial Privacy Act of 1978 20  
Firefox 35  
firewall 13  
FireWire port 12  
flag 134  
float 79  
floating point 79  
floating point numbers 10  
    comparing 106  
Float class 253  
flowchart 66  
flowchart symbols 67  
FlowLayout manager, Swing API 281  
folders 11  
format() method 64  
formatting output 64  
Fortran 5  
for statement 240  
    array iteration, traversing 241  
    nested 248  
frame, Swing 275  
front, queue 369  
functional decomposition 180  
Fundamental Theorem of Arithmetic 150

## G

### game

Adder 212, 335  
BirthdayGame 90  
Bowling 211  
Break-A-Plate 298  
Carnival 191  
DiceRolls 242

Dice Roll 210  
Game of 21 211  
GuessingGame 126, 151, 178  
Life 271, 336  
Mad-Lib story 333  
Mankala 272  
Mastermind 268  
Maze 363  
MyBoggle 364  
Nim 210  
Penny Pitch 270  
Rock Paper Scissors 114, 196  
TicTacToe 248  
WordGuess 141, 335  
generic collection classes 254  
get(), ArrayList 252  
getActionCommand(), JButton 278  
getContentPane(), JFrame 276  
getMessage(), Throwable class 313  
getSelectedItem(), JComboBox 288  
getText(), JTextField 285  
GIF 48, 292  
gigabytes 10  
gigahertz 2  
graphical user interface 3, 275  
greatest common divisor 153  
GridLayout manager, Swing API 282, 284  
GUI 3, 275  
Gutenberg, Johann 59  
Gutenberg Press 59

## H

hackers 21  
hailstone numbers 154  
HAN 6  
handheld computers 5  
handwriting recognition software 4  
hard-coded data 243  
hardware 1  
has-a relationship 187  
head, linked list 373  
heading tags 46  
heap 373  
helper method 182  
hexadecimal 9, 50  
histogram 268  
Home Area Network 6  
horizontal rule tag 46  
Hotmail 15  
HTML 35, 334  
    alignment 51  
    attributes 46  
    background color 50  
    comments 46  
    documents 36, 37  
    document tags 37  
    elements 36  
    hyperlinks 47  
    images 47

lists 46  
style sheets 49  
tables 47  
tags 36, 45  
text color 50  
validating 37  
HTML 4 45  
HTTP 16  
hub 8  
hyperlink 48  
hypertext 35  
HyperText Markup Language 35

I

identifier 77  
    choosing 88  
identity theft 20  
if-else if statement 108  
if-else statement 106  
    nested 107  
if statement 105  
IllegalArgumentException 161  
IMAP 16  
immutable 139  
import, package 60  
import statement 81  
increment operator 135  
index 138  
index, array element 239  
indexOf(), ArrayList 252  
indexOf(), String class 140  
infinite loop 132  
infinite recursion 344  
information age 19  
information hiding 179, 182  
infrared signals 7  
inherit 186  
inheritance 59, 213  
initializing an array 240  
initializing an object 80  
ink jet printer 1  
inline comments 108  
inner class 188, 295  
input, getting from user 81  
input, getting from user in a GUI 285  
InputMismatchException 81, 89, 95  
input devices 1  
input file stream 314  
input stream 81  
input validation loop 149  
insertion sort 341  
insertion sort algorithm analysis 357  
instance 179  
instance methods 184  
instance variables 184  
instantiation 80  
instant messaging 15  
int 79  
Integer 253

Integer class 285  
integrated circuits 2  
Integrated Services Digital Network 14  
Intel 2  
interface 225  
    as data type 339  
    Comparable 339  
    console 275  
    graphical 275  
    implementing 225  
    implementing multiple 227  
    text-based 275  
interface, as variable type 339  
interface, object 181  
Internet 13  
    history of 13  
Internet Acceptable Use Policy 19  
Internet Explorer 15, 35  
Internet filtering software 19  
Internet privacy issues 18  
Internet services 15  
Internet Service Provider 14  
interpolation search 361  
interpreter 6  
    Java VM 62  
interpreting bytecode 62  
intranet 13  
intValue(), Integer class 253  
IOException 322  
IP address 18  
is-a relationship 213  
ISDN 14  
isEmpty, queue 369  
isEmpty, stack 366  
IT 22  
Itanium 2  
iteration 131  
IT Careers 22

**J**

Java 6  
    enabling 41  
java.awt 284, 291  
java.awt.event 280  
java.io 311, 314, 317, 319  
java.lang 63, 79, 80, 113, 225, 254  
java.lang.Double 254, 285, 316  
java.lang.Integer 253, 285, 316  
java.lang.Math 113, 128  
java.lang.Object 186  
java.text 86  
java.util 80  
java.util.ArrayList 252  
java.util.Random 110, 138  
java.util.Scanner 81, 110, 138, 140,  
    244  
JavaScript 38, 40  
javax.swing 275  
javax.swing.JFrame 276, 277, 278, 292  
javax.swing.JPanel 276

javax.swing.JTextField 285  
Java applets 41  
    adding color 43  
    drawing shapes 43  
    parameters 44  
    placing in an HTML document 44  
Java application 61  
Java Foundation Classes 275  
Java Runtime Environment 80  
Java Virtual Machine 41, 62  
Jaz drives 12  
 JButton(), JButton class 278, 293  
 JButton class 293  
 JComboBox(), JComboBox 288  
 JComboBox class 288  
 JCreator 41  
 JFrame class 276  
 JIT 62  
 JLabel(), JLabel class 277  
 JLabel class 276  
 JPanel class 276  
 JPG 48, 292  
 JRE 80, 191  
 JTextField 285  
 JTextField(), JTextField class 285  
 just-in-time compiler 62

**K**

K 11  
Kbps 14  
keyboard 1, 81  
keyword 88  
kilobytes 11  
knapsack problem 362

**L**

label, Swing API 276  
    for displaying an image 292  
LAN 6  
laser printer 1  
lastIndexOf(), String class 140  
layout, Swing API 281  
layout manager, Swing API 281  
leased/dedicated lines 14  
length(), String class 138  
length, array 240  
library 60  
Life 271  
    with GUI 309  
Linear Congruential Method 110  
linear search 246, 349  
linear search, algorithm analysis 246  
line feed character 314  
line terminator 314  
link 48  
linked list 373  
Linux 2  
list, linked 373  
listener, Swing API 279  
Listserv 16

Local-Area Network 6  
local scope 160  
log(), Math class 128  
log10(), Math class 128  
logical topology 8  
logic error 89, 132  
logistic equation 154  
long 79  
Long class 253  
loop, controlling iterations 134  
loop control variable 135  
loop structure 131  
lowercase, converting strings 138

## M

machine code 62  
machine language 5  
MACS 1  
Mac OSX Tiger 275  
Mac OS X Tiger 2  
magnetic technology 13  
mailing list server 16  
main() method 61, 62, 157  
mainframe 3  
main memory 2  
Majordomo 16  
makeEmpty, queue 369  
malicious code 21  
MAN 6  
mantissa 10  
Mastermind 268  
Math class 113, 128, 130  
maze 363  
Mbps 14  
median, determining 268  
megabytes 10  
megahertz 2  
member, accessing 80  
members, class 180  
memory, dynamic 373  
memory-resident 4  
memory keys 1  
mergesort 345  
mergesort algorithm analysis 357  
message, passing 193  
method 157  
    abstract 222  
    accessor 182  
    array parameter 241  
    body 159  
    calling 159  
    class 159, 184  
    declaration 159, 162  
    documentation 164  
    helper 182  
    instance 184  
    modifier 182  
    naming 160  
    overloading 162  
    overriding 186  
    parameters 160

returning a value 163  
testing 167  
test data 168  
writing 159

methods  
behavior of object 179

Metropolitan Area Network 6

microphone 1

Microsoft Internet Explorer 15

Microsoft Windows 275

microwaves 7

MLA 17

MLA Handbook for Writers of Research Papers, Fourth Edition 17

mobile computing devices 4

modem 14

modifier method 182

modular 193

modulus division 83

monitor 1

motherboard 1

mouse 1

MP3 players 5

multimedia 36

multiplication 83

multiprocessing 3

multitasking 3

multithreading 3

multiuser OS 3

Mylar 12

## N

native format 11

natural logarithm 128

necklace problem 153

nested class 188, 295, 374

nested statements 107

netiquette 9

Netscape 35

networked environment 7

networks 6  
benefits 6  
size classifications 6

network architecture 7

network interface card 6

network operating system 7

NET Act 18

new 80, 239, 248

newLine(), BufferedWriter class 318

newline character 63

next(), Scanner class 81

nextBoolean(), Scanner class 81

nextDouble(), Random class 110

nextDouble(), Scanner class 81

nextInt(), Random class 110

nextInt(), Scanner class 81

node 7

node, linked list 373

Not 112

notebook computer 4

No Electronic Theft Act of 1997 20

null 139, 240

NullPointerException 139

number  
converting type 84  
whole 77

number systems 9

numeric expression 83

## O

object 59, 80, 179  
argument 161

object, to be written to a file 322

object-oriented development 191

object-oriented programming 6, 59

ObjectInputStream 319

ObjectInputStream(),  
ObjectInputStream class 320

ObjectInputStream class 320

ObjectOutputStream 319

ObjectOutputStream(),  
ObjectOutputStream class 320

ObjectOutputStream class 320

objects, sorting 339

Object class 185, 213

object deserialization 319

Object parameter 186

object serialization 319

offset array index 243

online profiling 18

OOP 6, 59

Opera 35

operand 83

operating systems 2

operations, order of 84

operator 83  
relational 105

operators, built-in 83

operator precedence 84

Opteron™ 2

optical technology 12

Or 112  
evaluation 113

order of operations 113

out 63

outer class 295, 374

Outlook 15

Outlook Express 15

output, formatting 64

output devices 1

output file stream 317

output stream 63

overflow 132

overflow error 10

overloading, methods 162

overriding  
methods 214

overriding a method 186

overwriting a file 317

## P

pack(), JFrame 276

package 60  
documentation 80  
naming 61, 81

package statement 61

paradigm  
object-oriented 213

parallel processing 3

parameter  
array, two-dimensional 248  
Object 186

parameters 44  
array 241  
constructor 183  
method 160  
pass by value 161

parentheses 84

parseDouble(), Double class 285, 316

parseInt(), Integer class 285, 316

Pascal 5

passing an array 242

passing data to a method 160

pass by value 161

PC 1

PDAs 5

peer-to-peer network 7

Pentium 2

peripheral devices 1

persistent data 311

persistent media 11

petabyte 13

phishing 22

PI, Math class 113

piracy 21

pixel 281

pixels 42

pixel tags 18

platform 3

platform-dependent languages 62

platform independence 59, 62

PNG 48

polymorphism 59, 217

polymorphism, interfaces 339

pop, stack 365

POP3 16

ports 1  
Bluetooth 1  
FireWire 1  
parallel 1  
serial 1  
USB 1

post 164

postcondition, method  
documentation 164

postfix 135

pow(), Math class 113

pre 164

precondition, method  
     documentation 164  
 prefix 135  
 primary memory 2  
 prime factors 150  
 prime number 150  
 primitive data type 79  
     argument 161  
 primitive data type  
     array element 242  
 print() method 63  
 printer 1  
 println()  
     debugging 137  
     toString() 187  
 println() method 63  
 privacy 20  
 Privacy Act of 1974 20  
 privacy policy 18  
 private keyword 182, 215  
 procedural abstraction 157  
 programming language  
     first generation 5  
     second generation 5  
 program specification 59  
     modeling 213  
 program specification, modeling  
     191  
 prompt 82  
 prompt, in a GUI 285  
 pseudocode 66  
 pseudorandom 110  
 public 159  
 public keyword 159  
 public static void main(String[] args) 61  
 push, stack 365

**Q**

queue 369  
 quotation mark 63  
     in a string 63  
 quotient 83

**R**

RAM 2  
 Random Access Memory 2  
 Random class 110  
 random numbers 110  
 random walk 155  
 range, determining 268  
 read(), BufferedReader class 314  
 readDouble(), ObjectInputStream class 321  
 reading numeric and string data 82  
 reading objects 319  
 readInt(), ObjectInputStream class 320  
 readLine(), BufferedReader class 314  
 readObject(), ObjectInputStream class 320

Read Only Memory 2  
 real-time clock 2  
 real-time OS 3  
 real numbers 10  
 rear, queue 369  
 recursion 343  
 recursive algorithm, binary search  
     349  
 recursive algorithm, depth-first  
     search 352  
 recursive algorithm, mergesort 345  
 recycling 19  
 reference data type  
     array 242  
     interface 339  
     object 80  
     object parameters 161  
     polymorphism 217  
     String 139  
 relational operator 105  
 remove(), ArrayList 252  
 remove(), JPanel 276  
 remove, linked list 373  
 replaceAll(), String class 138  
 replaceFirst(), String class 138  
 reserved words 88  
 return statement 163  
 reusability 60  
     code 191  
 ring topology 8  
 ROM 2  
 rounding 84  
 rounding double to int 85  
 roundoff error 11, 106  
 router 8, 14  
 run-time error 89  
     array 240  
 running a program 62  
 running time 356

**S**

Safari 35  
 Safety and Freedom through  
     Encryption Act of 1999 19  
 scanner 1  
 Scanner object, closing 82  
 scope 135  
 scope, local in a method 160  
 scripts 38, 40  
 SDK 42  
 search, binary 349  
 search, depth-first 352  
 search, interpolation 361  
 search, linear 349  
 search, sequential 349  
 search, ternary 361  
 searching an array 246  
 Search class 246  
 search engines 16  
 secondary memory 2  
 seed, for random numbers 111

selection sort 270, 337  
 selection sort algorithm analysis  
     356  
 semantic error 89  
 semicolon 62  
 sentinel 134  
 sequential file access 313  
 sequential search 349  
 Serializable interface 322  
 server 7  
 setActionCommand(), JButton 278  
 setBackground(), Swing API 291  
 setContentPane(), JFrame 276  
 setDefaultCloseOperation(), JFrame  
     276  
 setDefaultLookAndFeelDecorated()  
     ,JFrame 276  
 setEditable(), JComboBox 288  
 setForeground(), Swing API 291  
 setIcon(), JButton class 293  
 setSelectedIndex(), JComboBox 288  
 setText(), JLabel 277  
 setVisible(), JFrame 276  
 short 79  
 short-circuit evaluation 113  
 Short class 253  
 simple interest 103  
 sin(), Math class 130  
 size(), ArrayList 252  
 size, queue 369  
 size, stack 366  
 smartphones 5  
 social implications of computer  
     use 19  
 software development 157, 191  
 solid state technology 13  
 sorting, numbers 337  
 sorting objects 339  
 sorts 337  
 sound cards 1  
 source code 62  
 spam 16  
 spec 59  
 spyware 18  
 SQL 5  
 sqrt(), Math class 113  
 square root 113  
 SRAM 2  
 stack 365  
 startsWith(), String class 140  
 star topology 8  
 statement 61  
 state of an object 179  
 static 159  
 static method 184  
 Static Random Access Memory 2  
 static variables 184  
 step-wise refinement 157  
 Step command 136  
 storage, file 311  
 storage devices 12

storage media  
     care of 13  
 stream 313  
     input 81  
 string 63  
     formatting 64  
 strings 79  
     comparing 140  
     creating 138  
     joining 138  
 String class 79, 138  
 student expectations vii  
 style sheets 49  
     class 50  
     embedded 49  
     linked 50  
     rules 50  
 stylus 4  
 subclass 214, 217  
 subclasses 185  
 subject tree 17  
 substring(), String class 138  
 subtraction 83  
 summing values 133  
 Sun's Java Software Development Kit 42  
 superclass 185, 217  
     Object class 213  
 supercomputer 3  
 super keyword 215  
 Swing API 275  
 switch statement 109  
 syntax error 62, 88, 132  
 System.in 81  
 System class 63  
 system reliability 22  
 system restore 4

**T**

tablet PC 4  
 tab character 63  
 tail, linked list 373  
 tan(), Math class 130  
 TCP/IP 14  
 telecommunications 14  
 terabyte 13  
 ternary search 361  
 text field, GUI 285  
 this keyword 189, 279  
 thread 278  
 Throwable class 313  
 Tim Berners-Lee 36  
 toCharArray(), String class 244  
 toDegrees(), Math class 130  
 toLowerCase(), String class 138  
 top, stack 365  
 top-down design 157  
 top-down development 157  
 topology 7  
 toRadians(), Math class 130

toString() 186  
 toString(), Double 285  
 toString(), Integer 285  
 toUpperCase(), String class 138  
 transmission media 7  
 traversing  
     array 240  
     ArrayList 254  
 trim(), String class 138  
 Trojan horse 21  
 true 79  
 truncate  
     modulus division 83  
     toward 0 84  
 truth table 112  
 try-catch-finally statement 312  
 twisted-pair wiring 7  
 two-dimensional array 247  
     accessing elements 248  
 type casting 84, 245  
     generic collection classes 254  
     object 186  
     objects 254

**U**

ultra-portable devices 12  
 underscore (\_) 87  
 Unicode 10, 79, 244, 314, 381  
 Unicode Standard 140  
 Unix 2  
 uppercase, converting strings 138  
 USB 12  
 utility program 4

**V**

variable 77  
     class 180, 184  
     initializing in a class 183  
     instance 184  
     in println() 78  
     member 181  
     state of object 179  
 variable trace 136  
 video adapters 1  
 virtual 62  
 Virtual Machine 62  
 virus 21  
 visibility 159, 182  
     subclasses 215  
 Visual Basic .NET 6, 62  
 visual organizer 66  
 VM 62  
 void 159

**W**

W3C 36  
 WAI 44  
 WAN 6  
 Watch window 136  
 wearable computers 5  
 Web 15  
 website 35  
 website citations 17  
 Web Accessibility Initiative 44  
 web beacons 18  
 web browser 15  
 web browsers 35  
 web bugs 18  
 web directory 17  
 while 131  
 whole number 77  
 Wi-Fi 8  
 Wide-Area Network 6  
 Windows 2  
 Windows media player 44  
 Windows XP environment 3  
 WinZip 11  
 wireless access point 8  
 Wireless Fidelity 8  
 wireless networks 8, 14  
 wireless transmission media 7  
 words 10  
 World Wide Web 15, 35  
 World Wide Web Consortium 36  
 worm 21  
 wrapper classes 253  
 wrist-top computers 5  
 write(), BufferedWriter class 318  
 writeDouble(), ObjectOutputStream class 320  
 writeInt(), ObjectOutputStream class 320  
 writeObject(), ObjectOutputStream class 320  
 writing data to a file 319  
 WWW 35  
 www.sun.com 80

**Y**

Yahoo! 15

**Z**

Zip drives 12

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